Journal
of the
British Interplanetary Society

Vol. 11, No. 2 XLV March, 1952

PROBLEMS OF ASTRONAUTICAL RESEARCH

By Dr. Eugen Sänger

(*President of the International Astronautical Federation, and Honorary Fellow of the British Interplanetary Society*)

EDITORIAL NOTE

We received the manuscript of this article from Dr. Sänger early in November last year. A covering letter explained that he wished it to be regarded as a supplement to Dr. Loeser's article, *The First Task of an International Federation—an Institute for Astronautics* (*J.B.I.S.*, **10** (4), July, 1951). Added interest to such proposals is given by the UNESCO conference, held in Paris recently, to discuss the feasibility of establishing, somewhere in Europe, an "Institute for Advanced Studies in Nuclear Research," to be run as a truly international co-operative effort. With the intended object that all its work should be published, and concerned only with the non-military applications of atomic energy, this project has many points of striking similarity to the schemes of Dr. Sänger and Dr. Loeser. If it is successfully realized, it may constitute a valuable precedent in the years to come, and so point the way to future similar action in the astronautical field.

To a far greater extent even than was the case for aeronautics, astronautical studies will both influence, and be influenced by, all fields of human knowledge. Especially from a contemplation of the eventual effects of astronautics, one realizes how profoundly the development and ultimate destiny of all mankind is determined by the creative activities of those, relatively few in number, who constitute its intellectual leaders.

(1) Even in the domain of the *pure arts and social sciences*, various problems emerge in relation to astronautics. The history of the space-travel idea, its philosophical background and psychological motivation; sociological, political and economic consequences of its realization; literary and artistic influences; questions of language and philology; the need to revise many legal concepts, and indeed even some of our present religious or ethical ideas—all these may be mentioned. It is submitted that such problems, no less than the more obvious ones raised by the physical sciences, belong properly to the field of astronautical research.

(2) In the *general natural sciences* we must recognize the need to enlarge our knowledge of many branches of pure and applied mathematics, astronomy, astrophysics and meteorology. We face new problems of biology, medicine and psychology, amongst which perhaps the more important concern the physical and mental reactions of human beings to conditions involving absence of effective gravitation, exposure to cosmic radiation and to artificial or extra-terrestrial environments—in space itself, on other planets, etc. We must not forget to consider, also, the similar effects on the whole human race of contact

with other worlds; many geographical, geological and geophysical problems will then have to be regarded in a new light.

(3) Of course, the basic problems of astronautical research are mainly concentrated in the whole field of *physics*. Our fundamental concepts of space and time, mass and energy, gravity and electro-magnetism, particle and wave, are immediately involved. Relativistic, quantum and statistical mechanics become (for certain purposes) the methods required for common use. From the fundamental domains of photonics, electronics, nuclear physics, atomic physics and physical chemistry, our interest passes without interruption, via thermodynamics and gas kinetics, to aerodynamics and the physics of solid bodies. There are no clear barriers between these different aspects of physics, for our purpose; our interest must embrace them all. Any question concerning the equivalence of space and time, or mass and energy, is a central problem for basic astronautical research. So also is the generalized physics of flowing media that are not only compressible, but can also have a finite free path length for their particles, or which can suffer chemical or physical reactions and transformations, and have relaxation times for the establishment of their equilibria, corresponding to varying mixtures of photons, nuclear particles, atoms, molecules, radicles, and perhaps even dust particles, or which move with velocities approaching that of light—and so on. Other basic problems concern phenomena at boundary surfaces between such media and solid bodies, beginning with simple heat transfer and ending with cathodic dispersion and optical reflection or absorption.

(4) In the field of *chemistry*, research problems become more concrete, being concerned with the search for the best structural and mechanical materials and propellants. For the latter, the well-known considerations apply, of obtaining the highest possible effective energy concentration per unit mass, and per unit volume, while still retaining reasonably easy availability, storage, handling, etc. With the advent of nuclear power, there will be introduced other material problems—of nuclear propellants with controllable reaction times, of suitable inert working fluids, and of the best shielding materials. Specialized problems will undoubtedly be involved in the selection of the best materials for the varying requirements of power plants for various types of rocket aircraft, artificial satellites, spaceships and extra-terrestrial bases.

(5) The special problems of *technology* will concern the techniques of working and joining new materials, when fabricating novel structures. These problems will be intensified, and probably demand entirely new construction methods, when the work has to be done out in space, in a free orbit, or possibly on the surface of some other planet.

(6) In the field of engineering, the number of problems becomes immense—for instance, in *jet propulsion* (using the term in its broadest sense). Its basic theory, its efficiency, the design principles of the components (combustion chambers, jet nozzles, diffusers, injectors, burner heads, cooling systems, propellant pumps, tanks and control valves, starters, igniters, measuring instruments)—all these are some of the typical subsidiary problems requiring attention. They will arise in quite different forms, however, according to whether the "jet propulsion engine" concerned is of a type that consumes

air, burns chemical propellants, utilizes nuclear power, or represents some form of electronic or photonic drive. All of these may find specialized astronautical application.

(7) Similarly, the *jet vehicles* themselves introduce a mass of problems in the fields of mechanical and civil engineering. These concern the structural design selected, the methods and materials employed for its manufacture, its resulting weight, strength and performance, the necessary accessories and equipment, etc. Again, all these problems will occur in different forms, according to whether the vehicle concerned is a rocket aircraft, a spaceship which sometimes operates within an atmosphere, an artificial satellite, or a true interplanetary (or even interstellar) spaceship.

(8) The *flight dynamics* of jet vehicles is essentially a branch of applied physics, but of course occupies a position of very special importance in astronautical research. It includes the analysis of take-off procedure, the trajectory to be followed while traversing the atmosphere, the interplanetary (or interstellar) orbit, and the landing technique to be employed. Associated with these problems must be the development of the necessary equipment for control, observation and communication, to permit accurate following of the desired trajectories, navigation in space, etc. Thus, the subject has many common problems with experimental astronomy, but can also make use of aeronautical experience, especially in the field of applied electronics (radar, etc.).

(9) Finally, we must study also all those problems raised by the *ground installations and organizations* specifically required for space flight. These concern the societies already existing to-day, the necessary research plants, factories and development establishments, rocket test beds, airports (or spaceports!), air safety services (meteorological, astronomical, radio, etc.), propellant supply facilities, and indeed the whole complex supporting organization which will be demanded by space travel. In this field must also be included the technical problems of launching equipment, such as supersonic catapults, the astronautical federation and the endowment of its research institutions, and—eventually—the architectural and civil engineering problems of the first extra-terrestrial colonies, such as the lunar base.

The above enumeration of the problems of astronautical research clearly demonstrates that work on nearly all the natural sciences, in particular all theoretical physics, all aeronautical, atomic and astronomical research, is, in a sense, astronautical research—since it contributes, however indirectly, towards our aim. At first sight, therefore, it may seem audacious to claim that there is already a case for a specialized astronautical research institute. Certainly, such an institution would need to confine its early activities more particularly to the purely technical problems of space flight.

A most important and fundamental limitation to the development of astronautics arises from the fact that, under present conditions, a very large part of all aeronautical (especially jet propulsion) and atomic research is sponsored by the various national defence authorities. This of course prevents any free international exchange of information. However, there remain many astronautical problems which are without military significance, and are therefore likely to be neglected by the defence authorities, who will not be able

to afford expenditure on them while they also have to face problems of immediate strategic importance. In view of the expense involved, it is also unlikely that any other national body (i.e., other than the military) will attempt to deal with such matters. It follows that they would be the proper concern of a specialized international research institute, set up to deal purely with problems of space flight that have no military importance.

Another difficulty arises from the fact that, within the foreseeable (or at any rate immediate) future, the finance and facilities available for purely astronautical research will be strictly limited, so that extensive constructional work and practical experiment will be impossible because of their extremely high cost. However, all these difficulties do not mean that nothing at all can be done. Consideration of the matter shows that the proper sphere of activity for an astronautical research institute, in its early days, would lie somewhere in between basic and applied research—for there are wide differences between the relative costs of basic and applied research, development and manufacture on a large scale.

Over and above all these general considerations, however, it must be recognized that the programme of such an institute, in the last resort, must depend on the particular interests, qualifications, and personalities of the actual scientists available to form its staff. The following suggestions accordingly bear the stamp of the present author throughout:—

(*a*) The chief problem of astronautics is to obtain higher exhaust velocities than are so far realizable by the techniques of to-day. This task can be broken down into two parts: firstly, the realization of higher enthalpies in the propellant gases, either by employing extremely energetic chemical reactions (such as the combustion of fluorine and hydrogen), or else by the external heating or acceleration of inert working fluids, and secondly, the protection of the chamber walls against the higher temperatures resulting from the higher enthalpies (briefly, the energy transfer problem at the boundary surface). There seem to be excellent prospects for treating both of these parts of the basic problem with success, not only theoretically, but also by small-scale experiment using facilities of a kind reasonable for physical or chemical laboratories. The ramifications of the work seem so extensive that they could usefully absorb the capacity of one small research institution into the indefinite future.

(*b*) Detailed mathematical investigations of trajectories form a fundamental requirement for all future work in astronautics. In the first place, the trajectories of the cargo (or ferry) rockets to the space station, and then the orbit of the station itself, call for study, and so on. Such investigations can be undertaken successfully by a small mathematical staff in a calculations office equipped with the usual modern aids to applied mathematics.

Besides the two above projects, other work should only be undertaken by the institute, in its early days, if the results achieved in these two indicated its desirability, or if the means and staff available were suitably increased.

RESEARCH IN THE UPPER ATMOSPHERE WITH SOUNDING ROCKETS AND EARTH SATELLITE VEHICLES

By S. F. Singer, Ph.D.*

(*Office of Naval Research, U.S. Embassy, London*)

A paper based on a lecture given to the British Interplanetary Society in London on November 10, 1951.

ABSTRACT

Reasons are given why present upper atmosphere research is fundamental to the development of space flight; in particular, astrophysical research is believed to provide the main impetus for an Earth-satellite orbital rocket project.

A brief review is given of performance characteristics of high altitude sounding rockets in use in the U.S.A., of some techniques used in connection with rocket launchings and upper atmosphere experiments, and of results obtained from high altitude research, in particular those bearing on space flight.

Arguments are put forth for the establishment of an Earth satellite as a solar observatory outside the atmosphere to study ultra-violet, X-ray and corpuscular radiation from the Sun on a continuous basis and over a wide range of latitudes.

High Altitude Research and Space Flight

Perhaps something of an explanation is necessary for bringing such a down-to-earth topic as our own atmosphere before a Society interested in interplanetary flight. But there may be several very good reasons why the future of space flight is intimately connected with and dependent on present upper atmosphere research with high altitude rockets.

The most important reason, perhaps, is the fact that present high altitude rockets are becoming more and more the prototype of future space missiles, so that the experience gained from the design and operation of research rockets will lead gradually and naturally to the development of larger rockets reaching higher and higher altitudes. Of great importance undoubtedly are the various techniques which are being developed in connection with research rocket flights: such matters as rocket launching procedures, rocket control and radio communication, radar and optical tracking, design of instruments suitable for high altitude measurements, and radio telemetering transmission of data. This whole body of techniques has to be acquired and very thoroughly developed before we can even begin to think of getting away from our planet. Lastly, of course, the results obtained in upper atmosphere research have a direct relation to interplanetary flight. The study of the properties of the atmosphere itself is of the greatest importance in the design of a rocket vehicle which must leave the Earth, may circle the Earth, and may eventually return to the Earth. Further, conditions outside the atmosphere may have a bearing on humans or on the rocket vehicle itself; such phenomena as the ultra-violet emission from the Sun, primary cosmic rays and meteorites, and perhaps others. The

* During 1946–50 the author was associated with the High Altitude Research Group of the Applied Physics Laboratory, Johns Hopkins University (APL–JHU), Silver Spring, Md. Opinions expressed are the author's and do not necessarily represent those of the United States Department of Defence.

atmosphere shields us from many radiations which may have a profound influence on human existence as we know it; only by going above the atmosphere can we discover their existence and possible effects.

Finally, I believe that the ultimate justification for space flight will come from research, as indeed it should. Logically then the first step towards space flight would be the operation of the artificial "Earth satellite," an instrument-carrying orbital rocket circling the Earth many times at an altitude of perhaps 400 miles. The setting up of this astrophysical observatory beyond the Earth's atmosphere would undoubtedly be a major achievement in advancing our knowledge of the Universe.

Scope of High Altitude Research

High altitude research is a vast field, but by no means a new field. Research into phenomena occurring in the upper atmosphere has been carried on now for many hundreds of years from the ground, primarily through observations of aurorae, meteors and the anomalous propagation of sound; in this century through the study of the ionosphere and spectroscopic studies of the atmosphere. In recent years with the development of modern balloon techniques important advances have been possible, particularly in the study of cosmic rays and ozone, by carrying instruments in balloons up to altitudes of about 100,000 ft.

However, for many other investigations, some of them mentioned later, higher altitudes are necessary. This is simply due to the fact that although it appears that we can "see through" it, the atmosphere is not everywhere transparent. Incident on the top of the atmosphere from the outside are radiation (photons) and particles (corpuscles). The radiation is emitted principally by the Sun, but also by other stars and even by the very diffuse interstellar gas. This radiation is electromagnetic and includes long radio waves (having a wavelength of the order of metres), short waves, infra-red, the visible region, ultra-violet and X-rays (wavelength less than 10^{-10} metres). Due to the absorbing properties of the atmosphere, however, we can observe, at sea-level, only radiation in two very narrow bands: in the visible region (the region used for ordinary "seeing" of cosmic phenomena and objects), and in the radio frequency region from about 10 metres down to 1 cm. wavelength (this is, of course, the region used in radio-astronomy and solar noise measurements). All radiations of other wavelengths are absorbed and degenerated in various layers of the atmosphere. We are in an even worse position when we deal with incident particles. Those of low energy are soon brought to rest and our knowledge of their existence is indirect and uncertain (although very recently spectral measurements of aurorae have shown the existence of incident hydrogen atoms having a speed of 3,000 km. per second). Going on to higher energy particles, we soon reach the region of cosmic rays and there we are faced with a complexity of nuclear reactions which completely changes the character of the incident "primary" particles so that measurements at sea-level and even at balloon altitudes do not give us complete information about the character of the primary cosmic rays.

It is at this point where the rocket vehicle manifests its great usefulness for high altitude research by making accessible the regions above 100,000 ft.

This research can be divided into four general fields. The first is concerned with what one might call astrophysical phenomena, i.e., the study of radiation and corpuscles before they are absorbed or modified by the atmosphere: for example, primary cosmic rays, or ultra-violet and X-ray emission from the Sun. Here it is desired to carry the measuring instruments to an altitude sufficiently great to get above any disturbing influences of the atmosphere.

The second field, which might properly be called the geophysics of the Earth's atmosphere, is concerned with the study of the properties of the atmosphere at various altitudes and includes such measurements as pressure, temperature and density distribution, high altitude winds, the composition of the atmosphere and its state of ionization.

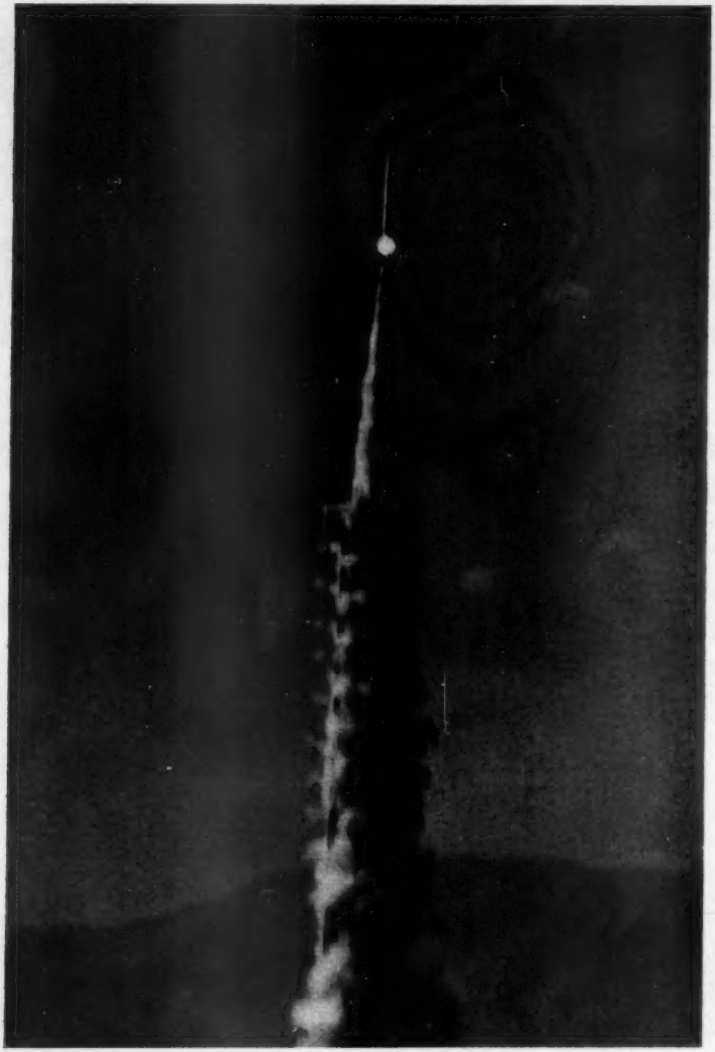
Thirdly, it should be pointed out that the atmosphere can be considered as a giant laboratory for studying a great variety of physical processes. We can learn things about nuclear physics by studying the transformations of the primary cosmic rays at various altitudes; we can consider the upper atmosphere an atomic physics laboratory by studying dissociation, ionization, etc., of molecules in collisions with incoming particles and photons; as a chemical laboratory where photochemical reactions* take place; as an electrical laboratory where large-scale motions of the atmosphere develop electromotive forces and produce large currents which profoundly affect the Earth's magnetic field; as a radio laboratory when we study the influence of the ionized layers on radio waves; and also as a laboratory of acoustics, hydrodynamics and mechanics when we study the propagation of sound, the tidal motions, oscillations and other large-scale motions of the atmosphere.

Lastly, of course, rockets can and have been used to study aerodynamics under conditions which are not easily reproducible in the laboratory.

Rockets as Vehicles for Research

In the United States high altitude research may properly be said to have begun in August, 1945, when a W.A.C. Corporal rocket carrying a payload of 25 lb. was fired to an altitude of 44 miles. This small research rocket, only 1 ft. in diameter and 16 ft. long, was developed by the Jet Propulsion Laboratory of the California Institute of Technology, Pasadena, California. Because of its restricted payload and altitude it never gained acceptance as a sounding rocket, but it is important to mention that it became the forerunner of the highly successful Aerobee rocket whose design was based to a large extent on the W.A.C. Corporal. The big impetus that started upper atmosphere research, however, was the capture by the U.S. Army at the end of the war of a number of German-built V.2 rockets. About 100 of these rockets were brought to the United States for military appraisal and testing. This programme started in 1946 and from the beginning invitations were issued to scientific groups throughout the country to participate in high altitude experiments and use the available space and payload of the rockets for scientific instruments. The V.2 is well known and has been extensively described in the literature; only its operational characteristics will be given here. The

* So important are these reactions, that Prof. J. Kaplan, of the University of California, Los Angeles, has proposed the name "chemosphere" for this region of the atmosphere.



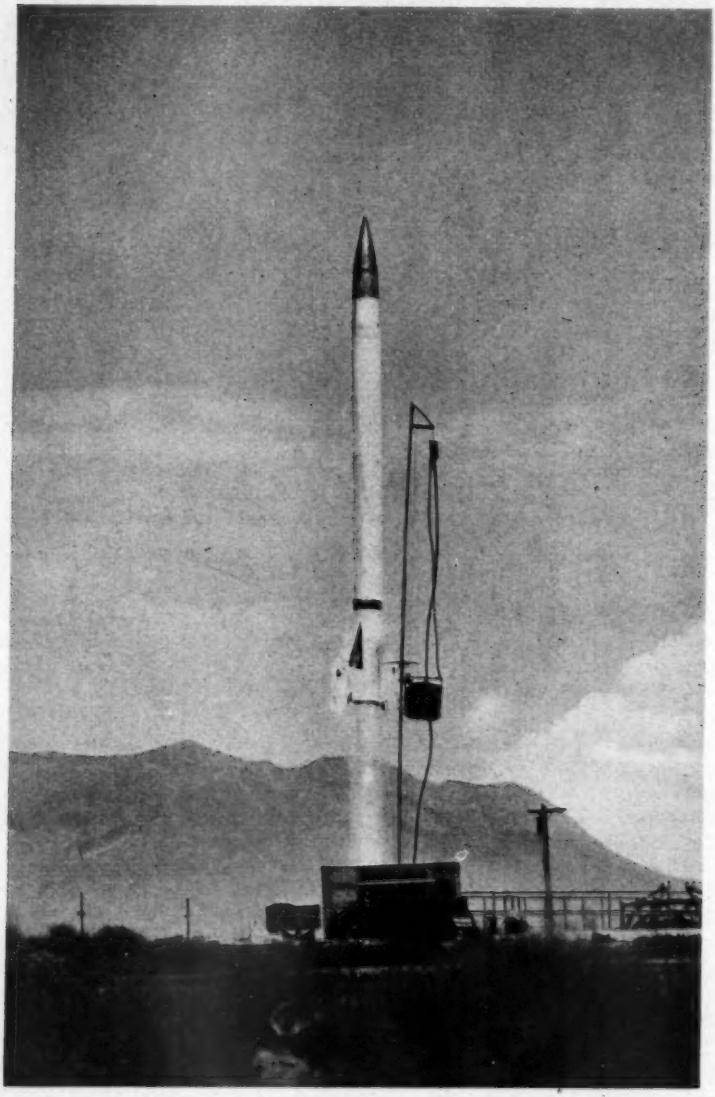
Aerobee rocket immediately after leaving the launching tower at White Sands Proving Ground, New Mexico (1947).

(*All photographs by courtesy of U.S. Navy*)

Fuelling one of the earlier V2 rockets at the White Sands Proving Ground, New Mexico. Photograph taken by L. W. Fraser of the Applied Physics Laboratory, Johns Hopkins University in 1946.

rocket is 47 ft. long and has a diameter of 5½ ft., a weight of 9,000 lb., plus 19,000 lb. of fuel and oxygen; its take-off weight then is 28,000 lb. The rocket motor develops a slow steady thrust producing a gradual acceleration which reaches about 6 *g* near the end of burning. Altitudes up to 600,000 ft. have been attained with V.2 rockets fired at the White Sands Proving Ground in New Mexico. However, many rockets reached only lower altitudes, and a large fraction, about 40 per cent., cannot be said to have given satisfactory performance. Even so, this figure exceeds the German success ratio in firing V.2 rockets. The main difficulty encountered with the V.2 is of course the fact that it was not designed as a sounding rocket for research purposes. It was definitely realized at the beginning of the high altitude programme that development of a new sounding rocket was necessary in order to replace the V.2's when their supply became exhausted. This development was initiated by Dr. J. A. Van Allen of the Applied Physics Laboratory, Johns Hopkins University, in Silver Spring, Maryland. The Aerojet Corporation, under contract to Johns Hopkins University, and with the support of the U.S. Navy, developed such a vehicle which was named the Aerobee.

The Aerobee is an extremely simple missile. It has no moving surfaces of any kind, therefore no guiding controls like the V.2. Stabilization is due entirely to arrow stability; this means that the rocket has to be fired from a launching tower to guide it initially and that sufficient means of acceleration



N.R.L. *Viking* firing at White Sands Proving Ground, New Mexico (1950).

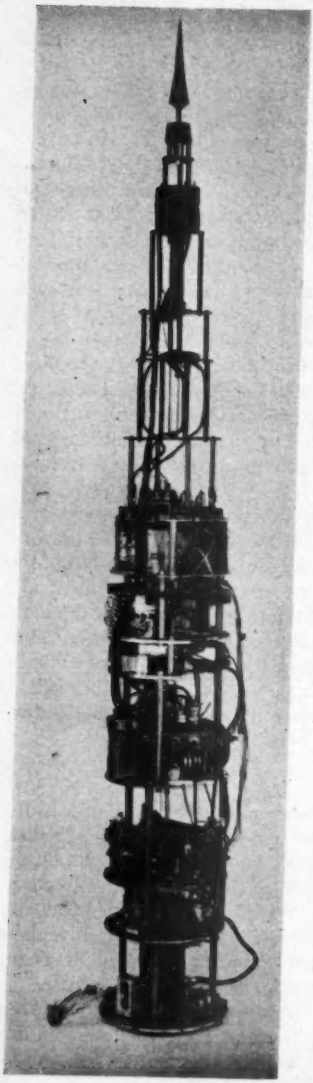
must be provided so that it will leave the launching tower with a high enough velocity in order to obtain a sufficient aerodynamic force on the rocket fins. This is accomplished by arranging propulsion in two stages. A solid propellant booster rocket develops high thrust at take-off, and brings the velocity of the rocket to about 1,000 ft. per second after 2 seconds of flight. The booster then falls away and the sustaining liquid fuel motor of the Aerobee takes over, gradually accelerating the rocket to a speed of about 4,000 ft. per second near an altitude of 100,000 ft. The maximum acceleration takes place during the booster phase and is about 12 *g*. Some 40 Aerobees have been fired and of these a very large percentage have been completely successful. Contrasted with the V.2 the Aerobee not only has the advantage of extreme simplicity and low cost, but it is also considerably easier to handle. The Aerobee can transport payloads of 150 lb. to about 400,000 ft. altitude. The unloaded rocket weighs only some 200 lb.; fully loaded and fuelled its weight is about 1,000 lb. Its length is only 20 ft. with a diameter of 15 in.

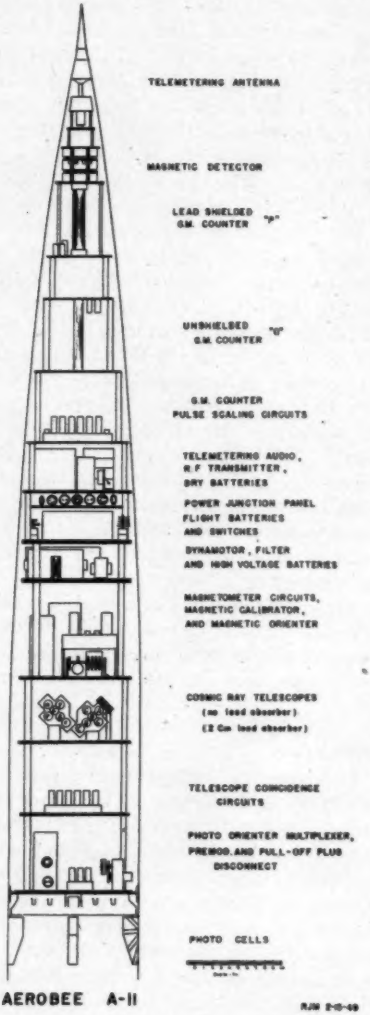
It might be worth mentioning the notable altitude achievement produced by a two-stage rocket, a W.A.C. Corporal, launched from the nose of a V.2 near the end of its propulsive period. This combination, fired by the U.S. Army Ordnance Department and the General Electric Co. on February 24, 1949, reached an altitude of 250 miles, the highest so far attained by a man-made object.

Recently, a large controlled rocket, the Viking, has been developed specifically for upper atmosphere research by the Naval Research Laboratory, Reaction Motors Inc. and the Glenn L. Martin Company. The Viking is similar in some respects to a V.2 but represents an entirely independent and new engineering achievement. It has a length of 48 ft., is 32 in. in diameter and weighs 11,000 lb. fully loaded. About seven Viking firings have taken place concurrently with continuing development of the rocket to carry 1,000 lb. to an altitude of 190 miles. It is now at the stage of taking a 500-lb. payload to 135 miles, and already holds the present altitude record for a single stage rocket.

Techniques

The launching of rockets at a proving ground or from aboard ship brings with it the development of techniques for the handling of missiles, fuelling, pre-firing testing, launching, tracking and finally the recovery of data from the rockets either by radio telemetering or by the physical recovery of records. No detailed description can be given here of this large body of know-how which is being built up, except to mention its obvious importance in making a rocket launching successful in all respects. These factors become of increasing importance as larger rockets are built and fired. The experience gained on the launching ground has made it necessary already to modify some of our thinking on the design of large rockets, but since we are concerned here mainly with describing high altitude experiments in rockets, much will be omitted which is purely of interest to the rocket engineer. I might stress, however, what I consider the major difficulty in a rocket launching, namely, that of co-ordinating a large number of technical groups, each concerned with various




TELEMETERING ANTENNA
MAGNETIC DETECTOR
LEAD SHIELDED G.M. COUNTER "P"
UNSHIELDED G.M. COUNTER "U"
G.M. COUNTER PULSE SCALING CIRCUITS
TELEMETERING AUDIO, R.F. TRANSMITTER, DRY BATTERIES
POWER JUNCTION PANEL FLIGHT BATTERIES AND SWITCHES
DYNAMOTOR, FILTER AND HIGH VOLTAGE BATTERIES
MAGNETOMETER CIRCUITS, MAGNETIC CALIBRATOR, AND MAGNETIC ORIENTER
COSMIC RAY TELESCOPES
(no lead absorber)
(2 Cm lead absorber)
TELESCOPE COINCIDENCE CIRCUITS
PHOTO ORIENTER MULTIPLEXER, PREMOD. AND PULL-OFF PLUG DISCONNECT
PHOTO CELLS
AEROBEE A-II

Typical Aerobee instrumentation used by the Applied Physics Laboratory, Johns Hopkins University, in firings at the geomagnetic equator from the U.S.S. *Norton Sound* (March, 1949).

aspects of the launching, and assuring that all their complicated instruments are in working condition and ready before firing. It is always necessary to fix an exact launching time well in advance and then try to meet this deadline. This can become very difficult at times since many of our experiments make use of complicated and sensitive laboratory-type instruments designed for a particular high-altitude investigation. They cannot however be designed in a laboratory fashion since they must be able to withstand high accelerations, vibrations and aerodynamic heating encountered in flight. Other limitations of doing rocket experiments are of course the confined space and the limited weight available for instrumentation, the unpredictable gyrations of the vehicle after burn-out, and in particular the very brief time which is spent in the upper atmosphere—a total flight lasts perhaps 5 minutes. Since the apparatus is almost never recovered in a condition to allow post-flight testing, it must be very carefully designed so that every small part of it will work in a completely reliable manner independent of outside influences. It is clearly not possible to operate as one would in the laboratory where one can repeat a run many times over again; in a rocket experiment the first run must count. Since supervision of the experiment is not possible, the apparatus must not only be foolproof and trouble-free, but also be provided with some means of calibration to judge whether its performance has remained stable.

The problem of capturing data has been attended with great success. Radio telemetering methods have given almost 100 per cent. coverage and have been used extensively. In cases where physical recovery was necessary, as e.g., in camera experiments where photographic film is involved, the problem has been to reduce the damage caused by the impact. A procedure has been developed for breaking up the rocket by means of an explosive charge on the down-leg of its trajectory so as to spoil its aerodynamic shape and increase the air resistance. In this way the impact velocity can be reduced from about 3,000 ft. per second, where recovery is quite hopeless, to velocities of several hundred feet per second. The object, e.g., the film which is to be recovered, must of course be protected in a heavy metal cassette. The main remaining difficulty has been that of locating the impact area of the rocket in the large desert region of the White Sands Proving Ground. Quite recently new types of parachutes have been developed which give hope that recovery of even large pieces of equipment in an undamaged condition will become possible.

Some Results of Rocket Research

It is not possible within the framework of this article to give more than a glimpse of some of the results which have been obtained by means of rocket experiments. Such measurements as pressure, temperature and density distribution within the atmosphere are now being extended to higher and higher altitudes with improved techniques. Some of the methods used are extremely difficult and had to be developed specifically for rocket experiments. Upper air temperatures, for example, are determined by wedge-shaped oscillating probes which can be used for the measurement of Mach angles. The new information gives us quite a different picture of the atmosphere. It appears from a recent N.R.L. Viking flight to 220 km. that upper air

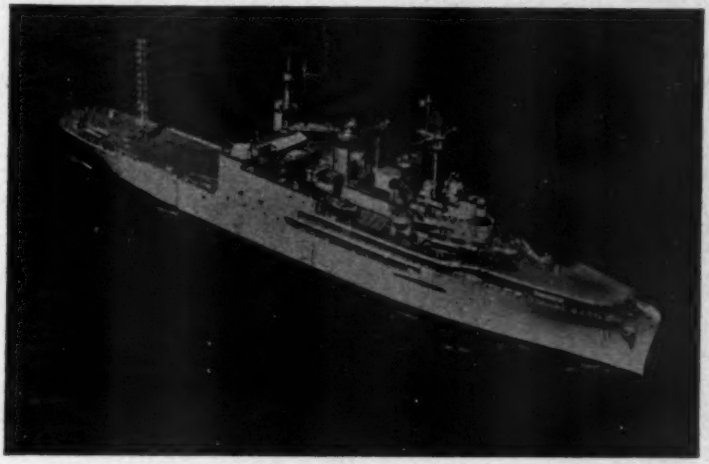
temperatures are very much lower than previously expected, with correspondingly lower pressures and densities at altitudes above 200 km. From the point of view of planning Earth satellite or interplanetary vehicles, knowledge of these properties of the atmosphere is of great importance. High altitude winds have been measured by means of smoke puffs and smoke trail experiments. The composition of the atmosphere is being determined directly with sampling bottles and with mass spectrometers carried in rockets. It has been possible to determine the vertical distribution of ozone, making use of its extreme absorption in the ultra-violet. Of great geophysical interest are the measurements on the Earth's magnetic field at high altitudes, indicating the existence of large current systems in the lower layers of the ionosphere. Direct measurements of ion and electron densities in the D- and E-layers of the ionosphere have been carried out by means of radio techniques; sky brightness and the air glow which exists in the upper atmosphere as a result of chemical activity there, are being investigated by means of photo-cells in rockets.

Among the studies which are of particular interest to interspace travellers because of their possible adverse effects are solar ultra-violet rays, meteorites and cosmic rays. Since the atmosphere protects us against these influences, it has been necessary to study them above the appreciable air layer. Our knowledge of the solar spectrum has been extended by means of spectrographs to wavelengths of 2,300 Å., and indirectly by means of photo-luminescent crystals and photon Geiger counters to the far ultra-violet regions of the solar spectrum. Using a variety of ingenious techniques, it has become possible to obtain information about X-rays which are probably emitted from the solar corona.

An interesting approach has been used to study the frequency of micro-meteorites above the atmosphere. Highly polished plates were mounted in the rocket skin and their pitting studied after recovery. These investigations are at present in a preliminary state.

With regard to the primary cosmic rays we now have firm knowledge of their distribution in energy. We also know that they are mostly composed of protons (hydrogen nuclei), but that there is a 15 per cent. admixture of helium nuclei and a 1 per cent. admixture of even heavier nuclei up to perhaps those of indium, all completely stripped of electrons and carrying tremendous energies. From the health hazard point of view it is perhaps this heavy component of the primary cosmic radiation which must be reckoned with most; the solar ultra-violet is easily absorbable and meteorites are judged to be quite infrequent. However, it appears to be difficult at present to assess the biological importance of bombardment by heavily ionizing and penetrating radiation. This problem and that of protection against the primary cosmic radiation must await further investigation.

Upper atmosphere research in the United States is being co-ordinated by the High Altitude Panel of the Research and Development Board. On this Panel are represented the leaders of the research and development described above; their groups are in the various branches of the U.S. Department of Defence, notably the Geophysical Research Directorate (Dr. M. O'Day) and



The seaplane tender U.S.S. *Norton Sound* used at various latitudes for cosmic ray and geomagnetic studies with rockets. An Aerobee rocket appears in the launching tower aft. Photograph taken by Dr. S. F. Singer, Applied Physics Laboratory, Johns Hopkins University, from ship's helicopter (March, 1949).

the Air Material Command of the U.S. Air Force, the Army Signal Corps (Dr. M. Ference), the Army Ordnance Laboratories (Dr. L. A. Delsasso) and the U.S. Navy. Basic research has been supported either by granting research contracts to University laboratories, as for example the Applied Physics Laboratory of Johns Hopkins University (Dr. J. A. Van Allen), or by the service agency doing the work at its own laboratories, in the case of the Navy at the Naval Research Laboratory (Dr. H. E. Newell).

Research in Earth-Satellite Vehicles

It might not be amiss to speculate about the next step forward in upper atmosphere research. Present sounding rockets after further development will soon reach altitudes suitable for the operation of the Earth satellite rocket. The question should be raised as to the feasibility of the project and as to its usefulness from the point of view of high altitude research.

In the first place, I think it is quite fair to regard the artificial satellite vehicle as a realistic project in terms of modern engineering knowledge. It has been said that the only major difficulty standing in the way of the orbital rocket is its cost, which would be of the order of 50 modern bombers. Put in these terms even the financial problem does not sound insurmountable, but much depends of course on the trend of current events. In this connection it is of interest to note that the cost of an Aerobee rocket compares very favourably with that of a naval torpedo, one hundred of which cost as much as a modern bomber.

I believe that there is little question that the satellite vehicle offers to

scientists a challenging opportunity for astrophysical research, in particular for solar research. The Earth satellite rocket can be visualized primarily as a solar observatory set up in an orbit above the atmosphere in which it circles the Earth over long periods of time, at least for several solar rotation periods (of 27 days each).

Without a doubt, the chief advantage of such a research vehicle over conventional sounding rockets (assuming the latter to reach the same high altitude) is the long time spent above the atmosphere, which can now be measured in weeks and months, rather than minutes. It is this feature which makes possible continuous observations of solar phenomena and allows the study of their development and variations.

To realize the full significance of this possibility one need only consider how little could be accomplished in the study of the ionosphere, or geomagnetism, or meteorology, if observations were made only a few times each year at one location.

In order to cover almost simultaneously the variation of some phenomena over a wide range of latitudes, it might also be proposed to direct the flight of the orbital rocket along a geomagnetic meridian. This would allow us to study the latitude deflection of solar corpuscular radiation due to the fact that the Earth's magnetic field can act as a momentum analyzer for corpuscular radiation reaching the Earth.

The main concern of the Earth satellite rocket is believed to be the coordinated study of the character, intensity and time relation of the emission of ultra-violet, X-ray and corpuscular radiation from the Sun. These are phenomena which can only be studied above the atmosphere, and at the same time those which may give us the most revealing information about solar processes.* A more complete description of solar processes will now be possible when the satellite data are correlated with solar phenomena which can be observed at sea-level, such as solar flares, the passage of sunspots, activity of the corona, radio noise bursts, aurorae, and geomagnetic and ionospheric disturbances.

Measurements of increases in ultra-violet and X-ray emission during intense solar activity are among the most valuable studies which can be made, because of their influence on our ionosphere and consequently on radio propagation; a properly instrumented satellite could therefore become a monitor of considerable practical importance.

The satellite is ideally suited for studying intensity variations of primary cosmic rays as a function of solar activity. By suitable instruments primary protons and heavier nuclei could be measured separately. As discussed above, by using the Earth's magnetic field the energy spectrum of the primary radiation can be measured concurrently and a reasonably complete description can then be given of the properties of cosmic rays which originate from the Sun.

* Accomplishment of these goals requires a very carefully thought-out set of instrumentation for the satellite rocket. In many cases these instruments would simply be developments of instruments already used for similar purposes in sounding rockets. In addition, of course, the orbital rocket must contain a power supply, multi-channel telemetering, and possibly stable-platform and Sun-follower devices which have already been developed for sounding rocket use.

A fascinating possibility would be the measurement of magnetic fields thrown out by the Sun and carried in streams of ionized gas. Such phenomena occur infrequently; they sometimes lead to severe disturbances of the geomagnetic field. They could be detected by a magnetometer located for long periods above the ionosphere where it would not be subject to ionospheric shielding effects.

A successful attack on these topics by means of the Earth satellite would constitute a pioneering advance in our study of the Sun. In turn it would lead us to a better understanding of the processes in other stars and perhaps shed light on the origin of cosmic radio noise and cosmic rays.

THE ARMSTRONG-SIDDELEY "SNARLER" ROCKET MOTOR

One of the interesting new developments unveiled at the S.B.A.C. Farnborough Show last September was the Armstrong-Siddeley "Snarler" A.S.Sn.1 rocket motor, and since that time a certain amount of further details have been released by the firm responsible. The following notes are based on the official Armstrong-Siddeley "hand-outs," one of which (we were pleased to note) concludes with the encouraging phrase: "Rocket propulsion is the only means by which travel in outer space can be achieved."

The "Snarler" gives 2,000 lb. of thrust at sea-level (with a slight increase at altitude), and weighs 215 lb. It is the first British rocket motor designed for the specific purpose of assisting the climb, top speed and manoevrability performance of fighter aircraft, especially at great heights, where the power of conventional engines (in contradistinction to that of rockets) falls away markedly due to the reduced air density. Because of the nature of this application, the main design considerations were safety and reliability throughout, with high performance and low weight regarded as secondary wherever they conflicted with the former objectives.

An experimental installation has been made in the Hawker P.1072 fighter, following an extensive period of ground testing of the power plant which culminated in the satisfactory completion of a special category flight clearance test. A considerable number of successful flight tests have also now been made; no actual performance figures from these have been released, but we are informed that, on his return from the first climb to 35,000 ft. in the P.1072, the late "Wimpey" Wade observed: "It goes up like a bloody rocket!" (Trevor Wade, the great Hawker test pilot, was subsequently killed while flying the P.1081, another new fighter prototype—not rocket-assisted.)

The P.1072 (also shown at Farnborough) is a modification of the Hawker N.7/46 naval fighter, with a Rolls-Royce "Nene" centrifugal type turbojet as its main power plant, the jet efflux from which is discharged through two tailpipes at the fuselage sides, just behind the wing trailing edge. This system of bifurcated tailpipes (originally adopted on the N.7/46 to permit accommodation of an extra fuel tank in the rear fuselage) therefore permitted a very convenient installation of the "Snarler" unit in the tail (see Fig 1).

The "Snarler" itself is shown in Fig. 2; it is a "dispersed" type unit, with

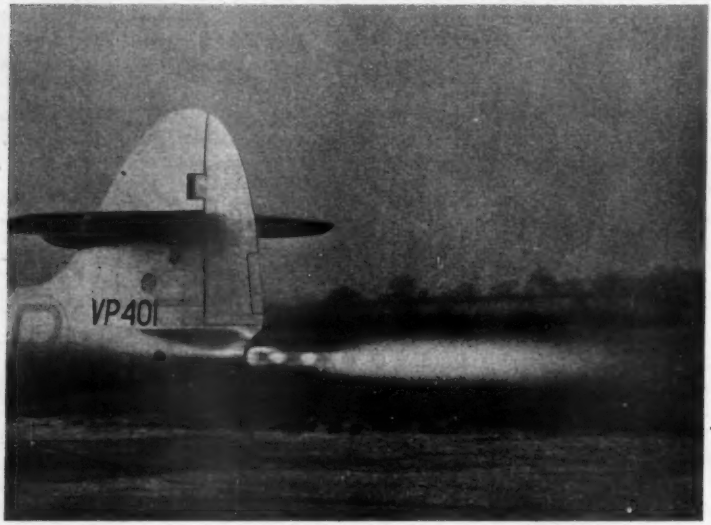


FIG. 1.

Flame issuing from Armstrong Siddeley "Snarler" Rocket Motor which is installed in tail of Hawker P.1072 Single Seat Aircraft. Part of the cowling is removed. Note the shock wave pattern in the supersonic rocket exhaust jet.

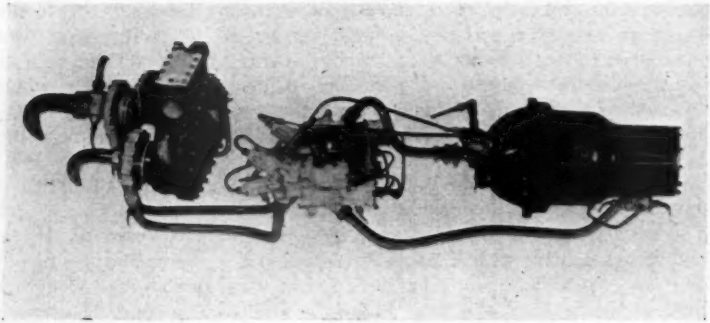


FIG. 2.

Armstrong Siddeley "Snarler" Liquid fuel Rocket Motor. This engine will run for as long as propellants are available in the aircraft tanks. Pump assembly on left, control valves at centre, combustion chamber on right.

the propellant pumps driven by an accessory drive from the main "Nene" engine, while the rocket combustion chamber is mounted at the extreme tail. In between, the various control valves are situated: in the figure all these components have been shown grouped closely together for pictorial convenience, connected by their various pipelines.

The "Snarler" uses liquid oxygen as its oxidant, and a methyl alcohol–water mixture as fuel, to obtain an acceptable combustion chamber temperature. The methanol–water fuel mixture is circulated through a coolant jacket surrounding the chamber, to provide regenerative cooling in the usual way. The designers state that they are satisfied that liquid oxygen is the best oxidant choice for aircraft rocket propulsion; although it has the disadvantage of boiling at −183° C. (with consequent high evaporation losses), it can be fairly easily handled, and can be made anywhere in the world (from air as a raw material) using mobile plants incorporating gas turbines as the prime movers of their compression and liquefaction apparatus.

One of the main hazards in rocket motor operation is obtaining smooth and certain ignition, without any delay during which a prohibitive quantity of liquid propellants might accumulate in the chamber. On the "Snarler," this problem is overcome by providing a small pilot chamber at the head of the main one. A small flow of fuel and oxidant is spark-ignited in this first; subsequently, when the hot gases discharged from the pilot chamber have lit the main chamber, the pilot chamber flow is cut off. This sequence of operations is determined by automatic valves, which also ensure that no propellants at all can be admitted to the main chamber until the ignition chamber has lit. The "Snarler" incorporates other safety devices also, which in general operate on the same philosophy—i.e., one operation is allowed to "trigger" the next, when it has become safe to allow it to occur.

The "Snarler" is controlled by two switches in the cockpit. One of these is a master switch, which stops or starts the motor, while the second selects either full thrust or part thrust. The motor can be stopped and re-started as required; if left switched on, it will run continuously for as long as it takes to exhaust the propellant tanks provided in the aircraft (normally, this would be a period of several minutes). If the selector switch is left at "part thrust," then the motor will run at this condition, but if "full thrust" has been called for, then it will automatically pass through the throttled condition to give maximum output, after ignition has been satisfactorily achieved. The makers point out that, although this "two-position" control has been adopted as meeting the requirements of the "Snarler" P.1072 installation, rocket motors in general are not limited to such a procedure. A more flexible, continuously-variable, thrust control can be provided if it is needed. (The Walter 109–509 motor in the Me.163, and the Curtiss-Wright motor for the new Bell X.2, both incorporate such a provision.—ED.)

During the last few years several B.I.S. members have participated in the design and development of the "Snarler.' They include Sidney Allen, M.I.Mech.E., A.F.R.Ae.S. (in charge of the project), and his assistant, Dennis Hurden, B.A., who delivered a lecture on "Rocket Motor Design" to the Midlands Branch on January 12.

GENERALIZED INTERPLANETARY ORBITS

By H. Preston-Thomas, Ph.D.

A recent article by A. C. Clarke[1] discussed some of the simpler properties of bodies moving in elliptic and hyperbolic orbits in the Solar system. It is the purpose of the present paper to continue this discussion to the point where we can obtain to a first approximation the time of flight and power requirements for a journey between any two specified orbits. The actual departure from the surface of a high gravity body such as the Earth will not be considered, but only journeys between satellite stations orbiting such a body and bodies with a low gravitational field. After considering the cases in which power is applied in one or more impulses during the journey—such orbits are the easiest to calculate and have minimum power requirements—some of the problems arising when power is applied over an extended period of time will be mentioned. In the writer's opinion this latter condition will almost invariably be encountered in interplanetary journeys.

It may be taken as an empirical rule that for a given power output—by which is meant the acceleration-time integral imparted to the ship by its motor, and which is most conveniently expressed as a change in velocity in kilometres per second—a journey from one to another stable orbit round a central body will be completed in the shortest time only if the power is applied in two impulses, one at the beginning and one at the end of the journey. (This no longer applies if the ship's orbit is perturbed by a third body during the journey.) Fig. 1 gives the time of flight in days against power requirements in km./sec. for various "twin impulse" orbits between the Earth's orbit and the perihelion point of the Mars orbit.* It is impossible to deduce directly the minimum time of flight for a given power expenditure, but we can obtain the complete solution of any orbit on being given the amount and direction of the initial thrust. Appendix 1 gives in detail a calculation, by one of several methods available, of total power and time of flight for an interorbital journey, the initial power and initial divergence of the ship's from the Earth's orbit being given. Fig. 1 has been constructed from such calculations. In this figure the point O is that resulting from the minimal ellipse which is tangent to both the Earth's and Mars' orbits. The curves A, B and C are those for orbits tangent to Mars' orbit, orbits tangent to Earth's orbit and minimal orbits respectively. While curves A and B may be computed directly, curve C cannot, but is the envelope of a family of curves of which D is a member. D shows times of flight against power for a constant initial thrust at the Earth's orbit—5 km/sec. in this case—and a varying initial divergence from it—shown in degrees at various points on the curve. These results show that it is more economical to osculate with the inner planet's orbit than with that of the outer planet, while the minimal orbits, except at O, osculate with neither planetary

* The orbits are simplified to the extent of being assumed to be coplanar and unperturbed by non-Solar gravitational fields.

orbit. This figure also shows the very considerable reduction in time of flight that occurs for a small increase in power over the requirements of the minimal ellipse at O. It should be borne in mind that for a journey on the minimal curve to take place there is a critical starting time from earth's orbit, many years elapsing before flight conditions will be repeated. For this reason it is probable that Mars will be contacted in positions other than the perihelion, in which case, if power is available above the minimal ellipse requirements, journeys may be commenced during a large part of each year. The curves shown will still be approximately correct under these conditions and they are, of course, valid for inward or outward journeys.

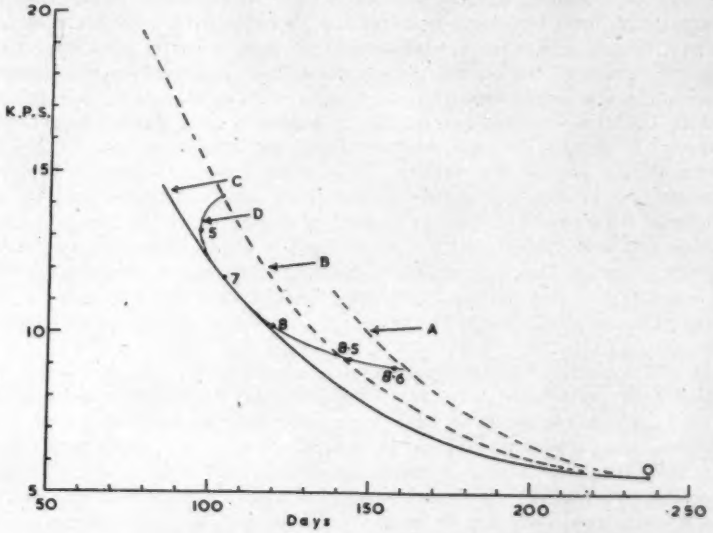


FIG. 1. Time of flight and power requirements for Earth-Mars transfers.

There next arises the question of escaping, with a velocity that will provide the required initial velocity in the interplanetary orbit, from a satellite station orbiting about a planet. If the initial orbiting velocity is V_o, the escape velocity, which is sufficient to remove the ship from the influence of the planet's gravitational field but which leaves it with no final velocity relative to the planet, is $V_o\sqrt{2}$, requiring, therefore, a velocity increment of $V_o(\sqrt{2}-1) = 0{\cdot}414V_o$. If the ship is required to have a finite relative velocity at infinity of V_f there must be applied an initial velocity V given by the relation $V = \sqrt{2V_o^2 + V_f^2}$. This equation shows that it is desirable to apply the thrust as close to the planet as possible. As an illustration suppose that a ship requires to enter the orbit O, Fig. 1—which needs 2·33 km./sec. in excess of the Earth's orbiting velocity—from a satellite station orbiting the Earth at 6,800 km. radius and a velocity of 7.70 km./sec. We can either apply 3·19 km./sec.

to bring the ship to escape velocity and then, when remote from the Earth, the further 2·33 km./sec. a total of 5·52 km/sec., or alternatively a single initial impulse of 3·44 km/sec. will also give 2·33 km./sec. when at an "infinite" distance from the earth. If a velocity increment of less than $0{\cdot}414V_o$ is applied, the ship will enter an ellipse and will return to the original thrust point where a further thrust may take place under the original favourable conditions. This technique of using multiple thrusts to escape will be dealt with in more detail below. Under certain conditions this "velocity transformation" may be used to effect a considerable economy in fuel. Consider a ship orbiting a planet at a considerable distance from the point of closest possible approach, i.e. based on a remote natural or artificial satellite. Instead of entering an interplanetary orbit by adding to its orbital velocity until it is excess of escape velocity, it may reduce the orbital velocity so that it enters an ellipse with a perigee "grazing" the central planet, adding the necessary excess velocity at perigee. The initial reduction in velocity will be least, i.e. zero, for an "infinite" orbiting radius, and for this condition Fig. 2 shows the velocity increment at perigee that will result in a required velocity at infinity for the planets Earth, Jupiter and Saturn. Thus in the case of Jupiter, a velocity at infinity of 11 km./sec. can be produced—or, of course, checked—by an impulse of 1 km./sec. (A velocity at least of this order will be necessary in a manned trip from Jupiter if the time of flight is to be reasonable, i.e. of the order of a year.) This technique of velocity transformation does not involve the abrogation of the first law of thermodynamics since the increased kinetic energy of the ship is balanced by the decreased potential energy of the exhaust gases.

If, in the course of an interplanetary flight, a ship approaches a planet its orbit will be perturbed. To a first approximation it may be considered as entering a hyperbola about the planet, its initial and final velocities *relative to the planet* being the same. The angle through which this velocity component is turned varies from zero to a maximum as the distance of closest approach decreases from infinity to grazing distance, and from 180° to zero as the relative velocity increases from zero to infinity. Under certain conditions such perturbations can result in a very considerable saving in fuel. If, for instance, a ship wanted to travel from Earth's orbit to a circular orbit 1·48 Earth radii from the Sun it could do it either by a direct minimal ellipse requiring initial and final thrusts of 2·75 km./sec. and 2·50 km./sec., a total of 5·25 km/sec., or it could enter the orbit O, Fig. 1, and go into a hyperbola round Mars thus entering a new ellipse with aphelion at 1·48 Earth radii, its initial and final thrusts being in this case 2·33 km./sec. and 1·31 km./sec., a total of 3·64 km./sec. Unfortunately no ship is ever likely to want to enter such an orbit, and in general it will be found that the planets are badly placed from the point of view of effecting fuel economies by such means. It can be stated in general terms, however, that grazing a planet *en route* can always effect some saving in fuel, that to increase this saving any velocity changes at that point in the orbit should be such that the relative velocity is increased after and not before grazing, that the heavier the planet the better—for a given density—and that the technique of velocity transformation previously referred to can be

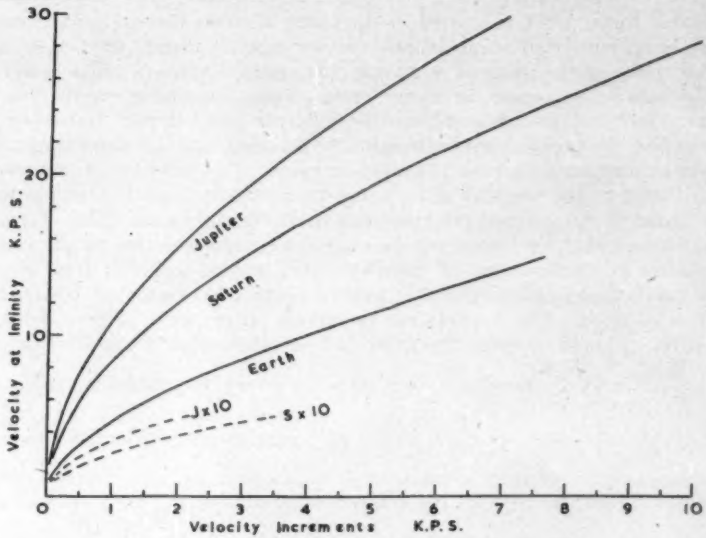


FIG. 2. Velocity transformation curves.

used. It should be remembered that owing to the position of the planets this method will seldom be of practical interest and also, in case the approach is misjudged, that all planets under certain conditions, and the major planets over a wide range of conditions, can convert a ship's elliptic orbit into a hyperbolic one, i.e. one that will take the ship out of the Solar System for ever, without any application of power.

A rocket motor burning chemical fuel will in general be able to give a ship an acceleration of the order of a tenth of a gravity or better, which in the case of most of the orbits considered is equivalent to an instantaneous thrust. It is desirable, however, to consider cases of ships of so low a power that they are capable of a velocity change of 1 km./sec. in a time ranging from 1 to 20 or even more days.[2] For these cases the general solution of an orbit produced when such a ship is accelerating continuously at full power, this power varying in a predetermined way, cannot be obtained, although individual cases lend themselves to solution with the aid of differential analysers. At least two special cases have been treated[3,4] although they are not, for several reasons, likely to be encountered in practice. In the limit, where they require no starting impulse and degenerate into spirals of zero divergence and infinite transit time, their power requirements for a transition from one stable circular orbit to another are a minimum and are equal, being given by $V = V_o\left(1 - \frac{1}{\sqrt{n}}\right)$ where V_o is the original orbital velocity and n is the ratio of the final and initial radii. It will be seen that this results in an incremental escape requirement of V_o compared with $0{\cdot}414V_o$ for the case of an impulse. Another type of

extended thrust orbit is treated in Appendix 2. This consists of a circular orbit being converted to an elliptic one by a small thrust, further thrusts taking place at the apogees of all the subsequent ellipses, so that power is applied always perpendicular to the gravitational field and along the line of flight. This treatment is valid only for infinitely small thrusts, but this case differs from the previous ones in that for the practical case of a finite thrust the power requirements decrease instead of increase. This will to a certain extent be balanced by the necessity of thrusting during a finite period of time so that the thrust is not always perpendicular to the gravitational field. It may thus be said that the above equation gives an approximation to the power requirements characteristic of extended thrust orbits, and that from it one may obtain an idea of the excess of power over the "twin impulse" power that will be required. Fig. 3 shows the power—in terms of the original orbiting velocity—required to transfer from one circular orbit to another where $n = \frac{R_1}{R_o}$. Curve C shows the twin impulse power requirements, given by $V = V_o\left\{\sqrt{\frac{1}{n}} + (n-1)\sqrt{\frac{2}{n(n+1)}} - 1\right\}$ (and shows incidentally that it may be easier to establish a remote orbit than a near one) while curve D gives the excess power required if the transfer is by way of an "ideal" continuous thrust orbit. This excess power is given by $V = V_o\left\{2 - 2\sqrt{\frac{1}{n}} - (n-1)\sqrt{\frac{2}{n(n+1)}}\right\}$. C′ and D′ are the initial portions of the two curves with their abscissae multiplied by 10. We have in general two types of orbit to consider. The first of these will be encountered in escaping from a planet's gravitational field, n having the value infinity and a large excess power being required for the continuous thrust case. The second type will be encountered in interplanetary flights, and if we consider that Jupiter, the asteroid belt and Mars are typical destinations, D′ shows that the excess power requirements will be respectively small, smaller and negligible. The values of D′ hold only in the case of the minimal ellipse, but considerations of practical values of transit times and accelerations show that the order of magnitude is correct for other cases. It may be assumed, therefore, that in interplanetary flights no substantial amount of extra power is needed when continuous thrust is substituted for impulse thrust.

Reverting to the problem of escaping from a planet, we can avoid the excessive extra power requirements by using the series of ellipses with constant perigee referred to earlier. The drawback to this system is that the periods during which thrust can be applied become progressively smaller as the ellipses are elongated. For example, for an ellipse round the Earth with perigee (R_p) 6,800 km. and apogee 235,000 km. with a period of 4·6 days and a perigee velocity of 10·76 km./sec. ($V_o\sqrt{2} = 10{\cdot}91$ km./sec.), the ship is at a radius less than $1{\cdot}02R_p$ for less than six minutes, an impracticably low proportion for thrust application. For this reason the type of escape orbit used will probably be a hybrid of the multiple ellipse type (Appendix 2) with its comparatively

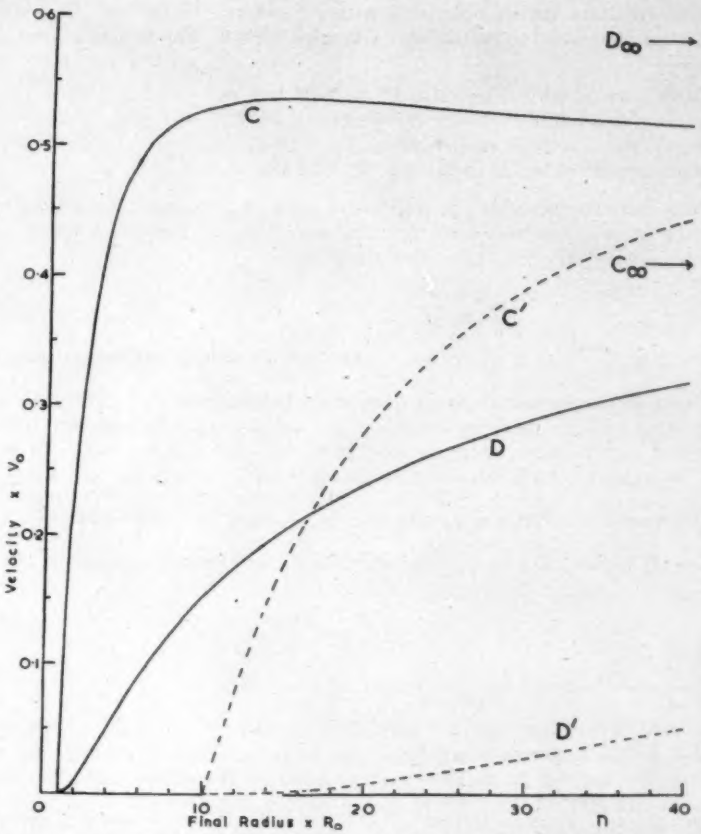


FIG. 3. Instantaneous and continuous thrust energy requirements.

long thrust times and the economical constant perigee system. It will be realized, of course, that low thrust ships cannot make use of the velocity transformation technique described earlier. Some of the practical problems arising from these considerations will be discussed in a later paper.[2]

Appendix 1

Calculation of time of flight and total velocity change requirements for an Earth-Mars orbit of given initial velocity change and deviation from earth's orbit.

This example considers an initial velocity change (v_e) of 5 km./sec. and an angular deviation (γ) of 8°. The transfer is from the Earth's orbit, assumed

circular, to Mars, arrival coinciding with perihelion. In this simple case the orbits are considered to be coplanar and unperturbed. The requisite constants are:—

Earth's mean orbital velocity, $V_e = 29{\cdot}76$ km./sec.
Earth's mean orbital radius, $R_e = 149{\cdot}5 \times 10^6$ km. $= 1$ unit.
Mars' orbital velocity at perihelion, $V_m = 26{\cdot}47$ km./sec.
Mars' orbital radius at perihelion, $R_m = 1{\cdot}382$ units.

The initial velocity of the ship in its orbit (V_{re}) is found by solving the triangle of velocities two sides of which are V_e and v_e and which has a non-included angle of γ, Fig. 4A. This gives:—

$$\alpha = \sin^{-1}\frac{V_e \sin\gamma}{v_e} = 55° 56'. \quad \therefore \beta = 116° 4'$$

and $V_{re} = \dfrac{v_e \sin\beta}{\sin\gamma} = 32{\cdot}27$ km./sec. (This is not a unique solution but neglects the case where the initial thrust reduces the orbital velocity.) In this—as in any other—ellipse the area swept by the radius vector in unit time (K) is constant and is given in the present units by:—$2K = R_e V_{re} \cos\gamma = 31{\cdot}96$.

The velocity of the ship (V_r), its distance from the Sun (R) and the semi-major axis of its orbit (a) are related by the equation (1):—$V^2_r = MG\left(\dfrac{2}{R} - \dfrac{1}{a}\right)$ where M is the mass of the Sun and G is the gravitational constant. Since $MG = V^2_e R_e = V^2_e$ this reduces to:—

$$V^2_r = V^2_e\left(\frac{2}{R} - \frac{1}{a}\right) \quad .. \quad .. \quad .. \quad .. \quad (1)$$

This gives $\dfrac{1}{a} = 2 - \left(\dfrac{V_{re}}{V_e}\right)^2 = 0{\cdot}8241$ or $a = 1{\cdot}2135$.

The next step determines the perihelion (q) and the aphelion (Q) distances and hence the semi-minor axis (b). Since at perihelion and aphelion, and only there, the direction of flight is perpendicular to the radius vector, at these points $V_r = \dfrac{2K.}{R}$ Substituting in (1) and solving the quadratic gives:—

$$R = a\left(1 \pm \sqrt{1 - \frac{1}{a}\left(\frac{2K}{V_e}\right)^2}\right)$$

This gives:—$Q = 1{\cdot}484$ and $q = 0{\cdot}9429$.
The semi-minor axis is now given by:—$b = \sqrt{qQ} = 1{\cdot}183$.

Fig 4B shows part of the ship's orbit, A and B being the points of contact with the orbits of Earth and Mars. The angle of deviation at B is $\dfrac{\text{SBS}'}{2} = \delta$. Since $\text{BS}' = 2a - R_m$, $\text{SS}' = 2(a - q)$ and $2a - q = Q$ we have:—$\text{SBS} = \cos^{-1}\left(\dfrac{2b^2}{R_m(2a - R_m)} - 1\right) = 20° 20'$, i.e. the angle of deviation at the Mars orbit is $10° 10' = \delta$. The ship's velocity at the Mars orbit (V_{rm}) is obtained

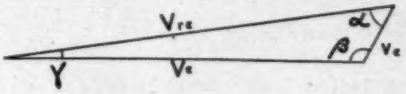


FIG. 4A. Initial velocity triangle.

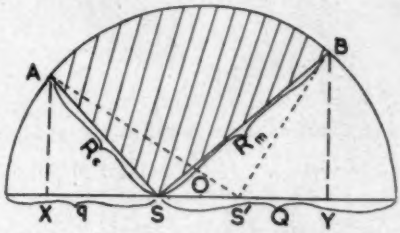


FIG. 4B. Orbit from Earth to Mars.

from (1):—$V_{rm} = V_e\sqrt{\frac{2}{R_m} - \frac{1}{a}} = 23{\cdot}50$ km./sec. Solving a triangle similar to that in Fig. 4A gives the magnitude of the second velocity change (v_m):—$v_m = \sqrt{V_{rm}^2 + V_m^2 - 2V_{rm}V_m\cos\delta} = 5.31$ km./sec., so that the total power requirement of the ship is given by $v = v_e + v_m = 10{\cdot}31$ km./sec.

To determine the time of flight, the area of the hatched section in Fig. 4B is divided by K. A further multiplication by the value of R_e in kilometres then changes the time unit to the second. The integration requires the values of OX and OY to be known. Solving the appropriate triangles gives:—

$$\mathrm{ASX} = 180 - \sin^{-1}\left(\frac{(2a - R_e)\sin 2\gamma}{2(a - q)}\right) = 46^\circ\,37'$$

$$\mathrm{BSY} = \sin^{-1}\left(\frac{(2a - R_m)\sin 2\delta}{2(a - q)}\right) = 42^\circ\,9'$$

$\mathrm{SX} = R_e\cos\mathrm{ASX} = 0{\cdot}6869$, $\mathrm{SY} = R_m\cos\mathrm{BSY} = 1{\cdot}0251$ and since $\mathrm{OS} = a - q$ $\mathrm{OX} = 0{\cdot}9575$ and $\mathrm{OY} = 0{\cdot}7545$. The area of the part of the ellipse between AX and BY is given by:—

$$\mathrm{A} = \frac{ab}{2}\left[\frac{x}{a}\sqrt{1 - \frac{x^2}{a^2}} + \sin^{-1}\frac{x}{a}\right]_{\mathrm{OY}}^{\mathrm{OX}} = 1{\cdot}831.*$$

$$\mathrm{A} = \frac{ab}{2}\left[\frac{x}{a}\sqrt{\frac{x^2}{a^2} - 1} - \log_e\left(\frac{x}{a} + \sqrt{\frac{x^2}{a^2} - 1}\right)\right]_{\mathrm{OY}}^{\mathrm{OX}}$$

The areas of the two unhatched triangles between AX and BY are given by:—$\triangle_x = \frac{1}{2}\mathrm{XS}^2\tan\mathrm{ASX} = 0{\cdot}250$ and $\triangle_y = \frac{1}{2}\mathrm{SY}^2\tan\mathrm{BSY} = 0{\cdot}475$ to give $\triangle = 0{\cdot}725$. This leaves a hatched area of $1{\cdot}106$, and dividing it by K and the appropriate factors to convert the time to days we have the time of flight

* Orbits to Jupiter and more remote planets will—if the transit time is to be within practical limits for manned ships, i.e. of the order of a year or less—be more nearly related to hyperbolas than ellipses. The treatment of a hyperbolic orbit is similar to that of an elliptic one, the only notable difference being in the integral.

given by:—$T = \dfrac{1{\cdot}106 \times 1{\cdot}495 \times 10^8}{15{\cdot}98 \times 8{\cdot}64 \times 10^4} = 119{\cdot}6$ days.

Note.—In computing the areas it must be known which sides of O and S A and B lie. The "changeover lengths" of AS and SB for these points are $\dfrac{b^2}{a}$ and a.

Appendix 2

Treatment of an orbit in which small thrusts are applied at the apogees of a series of ellipses. For a circular orbit $v = \sqrt{\dfrac{GM}{r}}$ and for an ellipse $v^2 = GM\left(\dfrac{2}{r} - \dfrac{1}{a}\right)$. If $\delta_1 v$ is a velocity increment that converts a circular to an elliptic orbit, v_o and r_o being the original orbital velocity and radius:—

$$(v_o + \delta_1 v)^2 = v_o^2 + 2v_o\delta_1 v = \frac{2MG}{r_o} - \frac{MG}{a}$$

$$= 2v_o^2 - v_o^2\frac{r_o}{a}$$

$$\text{Now } a = \frac{2r_o + \delta r}{2} = r_o\left(1 + \frac{\delta r}{2r_o}\right)$$

$$\therefore \delta_1 v = v_o\left(1 - \frac{r_o}{a}\right) = v_o\left(1 - \frac{2r_o}{2r_o + \delta r}\right) = v_o\frac{\delta r}{4r_o}$$

The velocity at apogee is given by:—

$$v_a^2 = MG\left(\frac{2}{r_o + \delta r} - \frac{1}{a}\right) = MG\left(\frac{2}{r_o + \delta r} - \frac{2}{2r_o + \delta r}\right)$$

$$= \frac{MG}{r_o}\left(2 - 2\frac{\delta r}{r_o} - 1 + \frac{\delta r}{2r_o}\right) = v_o^2\left(1 - \frac{3}{2}\frac{\delta r}{r_o}\right)$$

$$\text{or} \quad v_a = v_o\left(1 - \frac{3}{4}\frac{\delta r}{r_o}\right).$$

This ellipse is now converted to a circle by a second velocity increment $\delta_2 v$ at apogee. The orbital velocity required is:—

$$v_1 = \sqrt{\frac{GM}{r_o + \delta r}} = v_o\left(1 - \frac{\delta r}{2r_o}\right)$$

$$\text{Now } \delta_2 v = v_1 - v_a = v_o\frac{1}{4}\frac{\delta r}{r_o}$$

Therefore the total velocity change for the progression from one circular orbit to an adjacent one is given by $\delta v = \delta_1 v + \delta_2 v = v\dfrac{1}{2}\dfrac{\delta r}{r}$.

Putting $v = \sqrt{\frac{GM}{r}}$ gives $\delta v = \sqrt{GM}\,\frac{\delta r}{2r^{\frac{3}{2}}}$ and in the limit $dv = \sqrt{GM}\,\frac{dr}{2r^{\frac{3}{2}}}$

The power requirement to change from one to another stable circular orbit is therefore given by:—

$$V = \sqrt{GM}\int_{R_o}^{R_1}\frac{dr}{2r^{\frac{3}{2}}} = \sqrt{GM}\left[\frac{-1}{\sqrt{r}}\right]_{R_o}^{R_1}$$

$$= V_o\left(1 - \frac{1}{\sqrt{n}}\right) \text{ where } V_o \text{ is the orbital velocity at } R_o \text{ and } n = \frac{R_1}{R_o}.$$

REFERENCES

(1) A. C. Clarke, "The Dynamics of Space-Flight," *J.B.I.S.*, **8**, 71-84, March, 1949.
(2) H. Preston-Thomas, paper in preparation.
(3) G. F. Forbes, "The Trajectory of a Powered Rocket in Space," *J.B.I.S.*, **9**, 75-79, March, 1950.
(4) D. F. Lawden, Note on a paper by G. F. Forbes, *J.B.I.S.*, **9**, 230-234, September, 1950.

NOTES AND NEWS

The Third International Congress on Astronautics

Details have now been received from the Gesellschaft für Weltraumforschung of the arrangements for this Congress, which will take place at Stuttgart from September 1–6, 1952. The general theme of the Congress will be "Fundamental Problems of Space Travel Research," and there will be time for about sixteen papers of up to 30 minutes duration.

The provisional programme is as follows:—

SUNDAY, AUGUST 31.
20.00. Arrival of delegates at the Casino.

MONDAY, SEPTEMBER 1.
9.30. Opening of Congress and rocket exhibition at the Landesgewerbemuseum.
11.00. Press conference at the Landesgewerbemuseum.
14.00–18.00. Session of delegates at the Park-Hotel.

TUESDAY, SEPTEMBER 2.
9.00–12.00. } Session of delegates at the Park-Hotel.
14.00–18.00. }

WEDNESDAY, SEPTEMBER 3.
Day trip to Black Forest.

THURSDAY, SEPTEMBER 4.
9.00–12.30. } Technical papers at the Landesgewerbemuseum.
14.00–18.00. }

FRIDAY, SEPTEMBER 5.
9.00–12.30. } Technical papers at the Landesgewerbemuseum.
14.00–18.00. }
20.00–21.00. Lecture by Professor Dr. W. von Braun.

SATURDAY, SEPTEMBER 6.

9.30–12.00. Rocket films at the Technischen Werke, Lautenschlegerstr.

19.00. Reception by the G.f.W. and the City of Stuttgart at the Kleiner Kursaal, Bad Cannstatt.

Each Society will have two official delegates to the Congress, but other participants are welcomed. Any B.I.S. members who will definitely be attending are asked to notify the B.I.S. Secretary immediately so that lists can be prepared. The cost of board and lodging in Stuttgart is from 10 to 20 DM. (£1 to £2) per day.

Symposium on Medicine and Physics of the Upper Atmosphere, San Antonio, Texas

This important symposium took place on November 6–9, 1951, and was attended by about 40 authorities on aeronautics, astrophysics and medicine, as well as some 300 visitors. The meeting was opened by General Armstrong, Surgeon-General of the U.S. Air Force. The project was initiated by General Benson, Commandant of the School of Aviation Medicine, and organized by Dr. Clayton S. White, Director of Research of the Lovelace Foundation. Material presented at the symposium will be published in book form, probably in the spring of 1952, by the University of New Mexico Press.

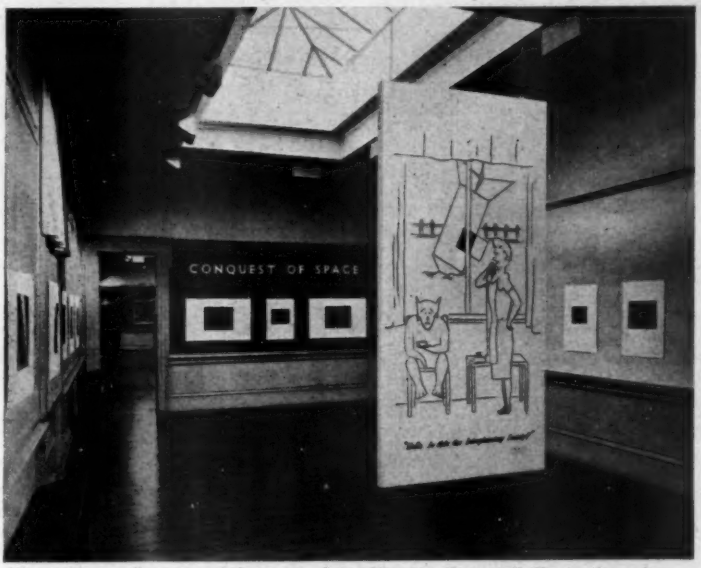
Among the many papers of astronautical interest the following may be noted: "Gravitation and Weight" (H. Haber); "Toxicology of Travel in the Aeropause" (H. Specht); "Meteoritic Phenomena" (F. L. Whipple); "Meteorites" (L. La Paz); "Thermal Aspects of Travel in the Aeropause" (F. Haber); "Problems of Thermal Radiation" (K. Buettner); "Solar Physics and the Atmosphere of the Earth" (M. Nicolet); "Ultra-Violet Radiation and X-Rays of Solar Origin" (T. R. Burnight); "Cosmic Ray Physics" (J. van Allen); "The Biologic Effects of Cosmic Radiation" (H. J. Schaefer); "Genetic Effects of Cosmic Radiation" (H. J. Muller).

In addition, a number of "round table discussions" took place, on such subjects as vehicles for high altitude research, "impact" and parachute recovery of equipment, radio telemetering, engineering techniques, visual and orientation problems and emergency escape.

It is hoped to give a fuller account of this symposium in the *Journal* when the volume of published papers is received.

Conquest of Space Exhibition, Sacramento, U.S.A.

On September 16, 1951, an exhibition of pictures and models on the theme of space-flight was opened at the Crocker Art Gallery, Sacramento, California, U.S.A. The *chef-d'oeuvre* of the display was a set of 50 Bonestell originals from *The Conquest of Space*. Also on exhibition was a scale model of the Solar System, occupying a length of 114 feet, astronomical photographs and instruments, a scale model of Mount Palomar Observatory, and a series of models showing the development of aviation. A most interesting display item was a five-foot model of the V.2-WAC Corporal step rocket, together with a portion of the WAC Corporal which had been recovered in good condition despite its 243 miles fall.



View of one gallery containing part of the fifty two Bonestall illustrations shown in the exhibit. A cartoon reproduced in large form from the B.I.S. *Journal* (originally from the "Manchester Evening News") is shown in the centre of the room.

Other pictorial matter exhibited included scratchboard drawings from K. Heuer's *Men of Other Planets* and originals from various interplanetary "comic strips." These appealed strongly (though not we suspect exclusively!) to the younger visitors.

Lectures by Professor Leon E. Salanave, Director of Sacramento College Observatory, and Dr. Dinsmore Alter, Director of the Griffith Observatory, attracted overflow audiences during the exhibition, which appears to have been a great popular success.

The illustration shows the gallery containing the Bonestell paintings—not to mention a cartoon reproduced from the *B.I.S. Journal*!

London Meetings

In view of the steady increase in the attendances at recent London meetings, the Council has made arrangements for all future meetings to be transferred to the York Hall (in Caxton Hall), which is much more commodious than our former venue in the Tudor Room.

In making this change the Council would like to take this opportunity to thank all those members whose support has contributed to so many enjoyable evenings, and especially those who have voluntarily endured a certain amount of discomfort while the new arrangements were being explored.

Compounded Subscriptions

The former scale for compounding annual subscriptions expired on December 31, 1951, and the Council has now approved the new scale reproduced below:—

Age Limits.	*Membership.*	*Fellowship.*
20–25	£36	£45
26–30	33	40
31–35	30	36
36–40	27	32
41–45	24	29
46–50	22	26
51–55	20	23
Over 55	18	21

Members who are able to compound their future annual subscriptions are reminded that by so doing they assist the Society greatly in providing a much-needed source of capital, with advantage to themselves also.

Dutch Astronautical Society

We are pleased to record the formation of the Nederlandse Vereniging voor Ruimtevaart (Dutch Society for Space Travel) on December 21, 1951, as part of the Royal Dutch Aeronautical Society. The Chairman of the Society is Dr. J. M. J. Kooy (co-author of *Ballistics of the Future*), and its Secretary is Mr. de Groot. The address of the N.V.R. is c/o K.N.V.v.L., Anna Paulownaplein 3, den Haag, Holland, and members will join us in wishing it every success.

Letter from Mr. H. P. Wilkins

We are very grateful to record the gift from Mr. H. P. Wilkins, F.R.A.S., of the new edition of his 100-inch map of the Moon.

Mr. Wilkins, who is Director of the Lunar Section of the British Astronomical Association, writes to us as follows:—

> "Far from considering interplanetary travel as 'very visionary,' I regard it as not only possible but a certainty. It is obvious that to achieve it will require such financial and other aids as to necessitate State action; if men really desired it and applied their resources the first space rocket would certainly be launched within 10 or 20 years. As matters now stand it will probably be much longer.
>
> "Since there are no insurmountable difficulties in attaining first the Moon and then the nearer planets, it is of importance to measure our knowledge of the physical features of these bodies as much as possible and this calls for much more careful and accurate observations than have so far been achieved. As regards the Moon, the object I had in mind when compiling my Moon map was the production of a chart which would show every little clump of rocks, within limits of course, every craterlet, pit, etc., so as to act as a reliable guide not only to telescopic observers but also to the explorers who might land on the lunar surface in the not too distant future. How far I have succeeded others must judge."

Mr. Wilkins has also very kindly offered to permit members who are serious students of astronomy to use his 15½-inch telescope for observations, by appointment only, after due notice has been given. The purpose of the intended observations should be made clear in the application: Mr. Wilkins regrets

that he cannot make his instrument available for general "star-gazing," but he welcomes those who have some definite programme in mind. Members interested in doing so should contact Mr. Wilkins at 35, Fairlawn Avenue, Bexleyheath, Kent.

B.I.S. or I.S.

A member recently suggested that it might be advisable to take steps to protect the name "The Interplanetary Society" on the grounds that it would prevent any later organization becoming registered and obtaining a *prima facie* seniority.

In reply to enquiries on this point, the Registrar of Companies has stated that the name "The Interplanetary Society" is too similar to our own to be registrable, and any request for its use would be refused.

Birmingham Film Visit

At the invitation of the manager, a party from the Midlands Branch attended a pre-view of the film *The Day the Earth Stood Still* at the Gaumont Theatre, Steelhouse Lane, Birmingham, on Tuesday, December 11, 1951.

The party consisted of ten members and visitors, who were very hospitably entertained by the management of the theatre.

Errata

We regret that two errors appeared in the article *The Air of Other Worlds* in the September *Journal*. On page 206 the velocity of the Martian winds was given as 7 km/sec.; this should, of course, have read 7 km./hour.

Mr. Firsoff also points out an error on page 208. The boiling point of carbon dioxide is *lower* than that of ammonia, so the result suggested does not follow.

Mr. S. W. Greenwood points out a correction in his paper "A Note on the Use of Dimensionless Parameters in Astronautics" which appeared in the September, 1951, *Journal*. The parameter V_j^2/θ used in equation (4) is not dimensionless; the appropriate parameter is $V_j^2/K^2\theta$, where $K^2 = 2G$, G being the Universal Gas Constant expressed in appropriate units.

$V_j^2/K^2\theta$ is proportional to the ratio between the effective exhaust kinetic energy per unit mass of fluid and the mean molecular kinetic energy of the gas prior to expansion.

Additions to Lending Library

The following additions have been made to the Society's lending library and are available on loan to Fellows holding library tickets.

Rockets, Jets, Guided Missiles and Spaceships, by J. Coggins and F. Pratt (1951).

Men of Other Planets, by K. Heuer (1951).

The Assisted Take-off of Aircraft, by C. M. Bolster (1950).

Radio Astronomy by Lovell and Clegg (1952).

From the World's Press

Flight for October 26 gave a long report of an address given in Chicago by Robert E. Gross (President of Lockheed Aircraft) to the American Bankers' Association. Much of it was concerned with the increasing cost, and staff requirement, for modern technical development—itself a theme with considerable relevance to astronautics. For example, it was stated that in 1943, Lockheed reckoned to have one fully-qualified and highly trained technical man to every 22 employees; now, with the increased complexity of new machines and their equipment, the ratio had to be one to eight. New aircraft designs carried about five times the weight of electronic gear, proportionately, as their predecessors: they were also faster, heavier, and more powerful, for a given duty, and so more expensive.

However, from our viewpoint, the most interesting of Mr. Gross's remarks concerned guided missiles, and were reported by *Flight* as follows: "The long-range guidance system, not the missile, was the key. In plain language, a guidance system which could get beyond the horizon was necessary, and for that it was necessary to bend a beam around the curvature of the Earth's surface. (He) could not speak of it on that particular occasion, but did say that the United States had a fine start on the problem." We have no idea what Mr. Gross was referring to; probably it was some system of long-wave radio navigational control—but it *could* be the Earth-satellite-vehicle, used as a radio relay station.

* * * *

Reviewing Clarke's "Exploration of Space" in *The Observer* of October 7, Charles Davy (the paper's science correspondent) made some mysteriously ominous remarks. "In relativity theory," he wrote, "space is connected with matter and gravitation, and the only space we can directly experience is bound up with the Earth's gravitational field. Can one feel sure that remote space, far from any planet, would be similarly experienced by human beings? . . . There may be tremendous surprises waiting for anyone who gets outside." Well, let's go see!

* * * *

Time for September 17 (and other papers, of course) reported that the United States Air Force had just placed contracts with the General Electric Co. for an atomic aircraft power plant, and with Consolidated Vultee (builders of the huge B.36) for an airframe to use it. No further details, understandably, were available. This news, coming soon after the United States Navy's announcement that it had ordered a nuclear-powered submarine, indicates the progress being made with reactors and their shielding for transport applications. *Life* for September 24 said the submarine would be built by the Electric Boat Co., of Connecticut, and its power plant was being studied by Westinghouse and G.E.C. The craft will have other things in common with future spaceships, besides an atomic power plant; for example, the provisions for supplying oxygen to its crew while it remains submerged for very long periods.

* * * *

Following very soon after the United States Navy's announcement that

its Douglas "Skyrocket" rocket plane had flown some 1,500 m.p.h. at nearly 80,000 feet, so beating the records of the Air Force's Bell X.I, news came of another Navy record. Its Martin "Viking" rocket, on August 7, reached a height of 135 miles, the highest altitude of any single-step design. Milton Rosen ("Viking" project engineer) said he expected the next "Viking" (the 8th) to go even higher.

* * * *

Time for November 19 reported the Symposium on space medicine held by the U.S.A.F. School of Aviation Medicine, mentioned the discussions on the possible dangers from meteors, cosmic radiation, and weightlessness, but concluded: "The space-planners are not dismayed, however, by the dragons that await them above the blue sky. The Air Force men seemed to take it for granted that manned rockets, even manned satellites and spaceships, are being designed already as serious, practical projects."

* * * *

In the diamond jubilee issue of its Journal, the American Chemical Society considered the next 75 years. "At least one man will have circumnavigated the Moon and returned safely," said Dr. Furnas of the Cornell Aeronautical Laboratory; Dr. A. V. Grosse (of Temple University) agreed, and thought the chemical propellant combination of liquid hydrogen and liquid fluorine might compete with atomic power to do the job.

* * * *

During November, a five-man team of British guided-missile experts arrived on the Australian rocket range to prepare for the final testing of new weapons; they included Mr. L. W. R. Robertson of the Armstrong-Whitworth Co.

An article on Woomera by John Paton in the *Egyptian Mail* gives an interesting description of the lonely settlement of pre-fabricated buildings, grouped around the airstrip, and says that "Two Samoyed dogs from Siberia (are) the only unscreened Russians within hundreds of miles."

* * * *

It is only very rarely that we see any news items of astronautical interest from behind the Iron Curtain, but in the last few months, most British papers have carried at least three.

During August, *Tass* reported the views of a Soviet scientist and astronomer, Gavriel Tikhov, to the effect that animal and vegetable life exist on Mars and Venus, and probably micro-organisms on Jupiter, Saturn, Uranus and Neptune. Tikhov was quoted as saying "Our researches show that life is an extremely persistent and pertinacious phenomenon. It can exist under conditions differing very much from conditions on Earth. Life can, and should, exist not only on the planets of the Solar System, but on planets which are moving near the innumerable stars inhabiting the endless universe."

Early in October, Mikhail Tokhonravov, a member of the Russian Academy of Artillery Science, wrote an article for *Pioneer Pravda*, a newspaper which is the organ of a Soviet youth organization. Dr. Tokhonravov predicted that

interplanetary flights would take place in time for many of his readers to participate in them, possibly within 10 or 15 years. He thought the first step would be the establishment of artificial satellite rockets; if these were used for refuelling a circum-lunar ship, it might weigh only 100 tons instead of 1,000. It was claimed that Russian rocket development was at least as far advanced as that of the Western powers.

Finally, in mid-October, the Soviet Navy newspaper *Red Fleet* printed an article by Dr. V. Abiants, a rocket specialist. Again claiming that the U.S.S.R. was far advanced in this field of study, the writer described a design for a Lunar spaceship. It would be nearly 200 feet long, 50 feet in diameter, weigh 1,000 tons, and be propelled by 20 liquid-propellant rocket engines of 350,000,000 total horsepower. Abiants admitted this rocket was still only "in the project stage"; he was also critical of the German wartime V.2, which he said suffered from various technical defects.

* * * *

Readers of this *Journal* will have read the separate account of the Hayden Planetarium Symposium, containing a discussion of the legal complications raised by space-flight, given by Mr. Schachter of U.N.O. Very similar views were expressed (and widely reported in the Press) during August by Mr. John C. Cooper, legal adviser to the International Air Transport Association. Pointing out that the Chicago Convention of 1944 binds national signatories to recognize "that every State has complete and exclusive sovereignty over the airspace above its territory," he commented:—

"If we accept the theory that the territory of the State extends as far upwards into space as required to prevent the entry of man-made activity which may result in injury to persons or property on the surface of the State, then we must assume that (an Earth-satellite-vehicle) is violating the sovereignty of every State below which has not consented in advance to its passage."

* * * *

During August, various British papers carried brief accounts of some experiments made in Switzerland with a model "landing rocket," in which German technicians had collaborated; *The Sphere* for August 18 printed a picture. Some contemporary issues of Continental papers alleged that breaches of traditional Swiss neutrality, and of regulations by the Allied Occupational Authorities in Germany, were involved, though all such stories were notably vague in their details. We refer members to the October issue of the G.f.W. *Weltraumfahrt* for a fairly full account. The trials, which were only partially successful, were intended to land personnel or stores by rocket braking. They were organized by Dr. Georges Lorenian, an Italian-born Swiss, and the German engineer employed was Ing. Heinz Gartmann, late of B.M.W.

* * * *

The *Evening News* (London) on September 3 quoted a Reuter report that the U.S.A. plans to spend £357,000,000 *before next July* (1952) on guided missiles.

Time for October 22 reported Professor Walter Prescott Webb, a Texas historian, as announcing that civilization's "400-year boom" is over, because civilized nations have no more geographical frontiers to push back. The comment was added, however, that the 300 people attending the Hayden Planetarium Symposium on space-flight in New York were too busy to hear this!

* * * *

Nearly all the Press reports of the S.B.A.C. Flying Display at Farnborough in September gave prominence to the Armstrong-Siddeley "Snarler" rocket motor shown there for the first time in public, and to the Hawker P.1072 jet fighter to which it is fitted as an auxiliary boost unit for improving climb, etc. Also, the bi-propellant research rocket, 24 feet long and 17 inches diameter, on the Ministry of Supply stand, attracted much attention.

* * * *

The trade journal *Shipbuilding*, reporting in August that the veteran cruiser *Cumberland* had completed her conversion into an experimental vessel for guided missile firing, commented also on the long naval history of rocket bombardment. The Congreve rockets of the Napoleonic wars, and Nelson's enthusiasm for them, and operations in the Crimean war, were recalled.

* * * *

After publishing a deplorable article on space-flight (about which the least said the better) in their August 11 issue, *Picture Post* printed a letter on the subject from our Chairman; this was followed by a reply from the author of the offending article, which, in at least one respect, can only be described as impudent, and then (on September 29) by a long review of Clarke's *Exploration of Space*. This last article was sufficiently favourable, we imagine, to have induced *Picture Post* readers with any interest in astronautics to read the book for themselves. Those who did will have gained some idea of what is known and believed, in informed circles, about our subject—which is more than they could have done from the original article.

* * * *

The October 1951 issue of *Aero Digest* (one of the leading American aviation magazines) was almost entirely devoted to articles on astronautics. The general theme linking these was a welcome affirmation of the belief that interplanetary flight was no longer to be regarded as a fantastic possibility of the remote future, but rather as a natural development soon of current work on guided missiles, etc. While the articles in question gave no new information (and, in the only mathematical example especially, betrayed a certain unfamiliarity with the subject), there can be no doubt that their publication in such an important magazine constituted valuable publicity.

The issue contained a number of interesting photographs of contemporary American rockets, and was notable for an implied assumption throughout (with what justification, we do not know) that the United States authorities are very actively engaged on an Earth-satellite-vehicle project.

The feature article in *Punch* for November 21 was entitled "The Interplanetarianists—or 'Forbes, Lay Out My Space Suit.'" Written by J. B. Boothroyd and illustrated by no less than the one and only Emett, it dealt very fairly and favourably (not to say wittily, of course) with the B.I.S. A preliminary to this effort involved a journey by the collaborators into the deepest space beyond Wood Green, with the object of meeting our Chairman. He tells us that his main impressions of the interview were (*a*) the *Punch* writer pleading with him to be *serious* about interplanetary flight, and (*b*) the shock of discovering that Emett was, not an elderly gentleman with drooping moustaches driving an ancient light locomotive (see your driving licence), but a smart young man with an equally smart sports car.

* * * *

The *New York Journal of Commerce* announced that the Solvay Process Division of the Allied Chemical and Dye Corporation have published a bulletin entitled "Safety Measures for Nitrogen Tetroxide." The substance was claimed to be of interest as a rocket oxidant.

REVIEWS

200 Miles Up

(By J. Gordon Vaeth. 207 pp., 62 figs., pub. The Ronald Press Company, New York. $4.50.)

Mr. Vaeth is an aeronautical engineer at the United States Navy Special Devices Center, Office of Naval Research, as well as a member of the A.R.S. and the B.I.S. He "graduated" into high-altitude research via balloons, and one of the most interesting chapters in his book relates to "Project Skyhook," about which little has been published in this country.

200 Miles Up is written for a wide public and avoids excessive technicalities or mathematics. It can be recommended to any layman interested in the upper atmosphere, but it will also be of value to the specialist as it contains in compact form a great deal of material hitherto scattered among scientific journals, or not available at all.

The opening chapters give a clear account of what is known about the "atmospheric ocean" and the methods of investigation now available—rockets, airplanes and balloons. Although the rocket reigns supreme at the highest altitudes, balloons have also made great advances during the past few years and the plastic "Skyhooks" can now take loads of 300 pounds to altitudes of 100,000 feet. Mr. Vaeth gives an interesting account of "Project Helios" —a scheme for a piloted balloon flight to 90,000 feet. Such a flight, according to the author, would not present any great technical difficulties, nor would it be very expensive. "Project Helios" was abandoned purely because of our present ignorance concerning the effect of cosmic rays upon human beings at high altitudes. The author believes that this subject has not been given the attention it should in studies of space-travel.

It is now definitely known that many of the so-called "Flying Saucers" sighted in the United States were in fact "Skyhooks"—as some of the photographs in this book make quite clear. According to Mr. Vaeth, "their translucent material gives them a strange and unusual appearance in the sky. Because of their size (100 feet in height) they can be seen by the naked eye at distances as great as 20 miles and more. They are often seen in various stages of inflation, being pear-shaped when fully inflated, and having a very long and narrow ice-cream cone shape when only slightly inflated. Their airborne appearance is unlike that of any other balloon type. Even the most experienced observer will not generally recognize an airborne "Skyhook as a balloon unless he has previously seen photographs. . . ."

Unfortunately, Flying Saucers cannot be disposed of as easily as this, because Mr. Vaeth gives in detail, with all the theodolite readings, what appears to be a "genuine" Saucer sighting—made by one of the "Skyhook" teams!

The last chapters give a lucid account of the work done in the United States with V.2's, Aerobees and Vikings. The simple and efficient Aerobee has already made a great contribution to science and the important launchings from the U.S.S. *Norton Sound*—which gave the first experimental evidence for electric currents in the ionosphere—are also described.

Mr. Vaeth concludes his book with a guarded section entitled "What Will Follow the Viking?" He thinks that space-flight is possible, but is not likely for a long time.

200 *Miles Up* is strongly recommended to all classes of readers as an accurate, non-technical summary of current high-altitude research. A. C. C.

Rockets in Cosmos

(By V. Gradecak. A MS. submitted by a member resident in Australia. Though unpublished, it is on file in the B.I.S. Library.)

This work constitutes a course in astronautics. It is designed apparently, to allow a person of moderate mathematical ability and no previous acquaintance with the subject to compute with a considerable degree of precision a number of rocket, satellite or planetary orbits. The author's insistance on simplicity of approach—overdone at times, since no one who is capable of applying perturbation theory to rocket orbits will need, for example, to be shown in three steps that $\frac{2H}{2a-r}-\frac{H}{a}=\frac{Hr}{2a^2-ar}$—coupled with the wide scope of his subject has resulted in 115 pages of single spaced typescript. This is divided into three sections, A, B and C. Section A provides an introduction to the subject, giving derivations of Kepler's and Newton's laws, various useful co-ordinate transformations, orbit elements, and a simple treatment of perturbations. By way of illustration Chapter 3 considers the Moon's orbit in some detail. Section C is in effect a detailed and extremely useful appendix defining symbols and simple formulae used in the text and giving in addition all necessary astronomical and mathematical constants and tables.

Section B includes the principle matter in the work. It deals with questions of satellite stations, earth satellite–moon satellite orbits and interplanetry

orbits, the last both with and without the aid of an ephemeris. The chapter on the space station, while considering orbits of greater radius than will probably be used, is particularly valuable in demonstrating the treatment of perturbations by the Sun and Moon, calculations for the correction of secular, i.e. long order cumulative, perturbations due to the Moon being given in detail. Figures enabling the method to be applied to orbits round the Moon, Mercury, Venus and Mars are included. The following chapter on the Earth-Moon orbits considers in fact only doubly osculatory satellite—satellite orbits which are set up and ended by instantaneous rocket thrusts. Once again the value of the chapter lies in its treatment of the orbit perturbations.

In the chapter on Earth-Mars and Earth-Venus orbits, the equations being applicable on changing constants to orbits between other planets, some numerical errors appear. For instance in the case of the doubly osculatory ellipse between Earth and Mars the accidental use of the semi-major axis instead of the perihelion distance of Mars results in the transit time being given as 260 days instead of the correct 240 days. A more serious error in another Earth-Mars orbit results in a 227 days transit time being substituted for the correct 90 days. This type of error is more or less trivial, however, since the underlying equations are sound. More serious from the point of view of the usefulness of the examples are the artificial limitations imposed on the orbits. The author assumes in all cases that the rocket thrust is effectively instantaneous. This is necessary if the orbits are to be readily computed at all, but it will probably not correspond to actual conditions. Less understandably the author requires that the orbits of the rocket and the non-terrestial planets shall be osculatory, although for a given transit time it is more economical in fuel to osculate with the inner planet and most economical to use a particular orbit, admittedly difficult to determine, that osculates with neither. These points might at least have been mentioned. In addition, with merely a brief introductory suggestion that the use of atomic power will solve the necessary fuel problems, the author cheerfully introduces orbits requiring total velocity changes—in two impulses of the order of 50 km./sec. Such orbits are, one feels, of more theoretical than practical interest.

Despite the foregoing and other limitations, *Rockets in Cosmos* is remarkably interesting since it deals with the existing Solar System rather than with that frequently evoked system in which planets move in unperturbed coplanar circles. The reader will, therefore, be introduced to methods of computation which are somewhat complex but which will certainly be required for the prediction of the first spaceship orbits. The value of the work might be considerably augmented if sections B and C were much further compressed—to about 30 pages—and issued as a separate handbook for the necessarily advanced student desiring to undertake accurate computation. The work as it stands would then do excellently—since text and figures are admirably clear—for students entering the field and for the more advanced students as an occasional revision text. Any revised text might, perhaps include more practical interplanetary orbits and even make a start on the vexed question of continuous thrust. In addition more specific references in the text to the bibliography listed at the end would be welcome. H. P.-T.

CORRESPONDENCE

Establishing Contact between Orbiting Vessels

SIR,

In treating the motion of particles which suffer a slight perturbation from a circular orbit, relative to unperturbed particles, Mr. Smith (*J.B.I.S.*, **10**, 295, Nov., 1951) states that: "It is rather surprising to find that if the new velocity is added or subtracted tangentially or radially the maximum displacement is still of about the same order (as for an addition at right angles to the plane of the orbit), that is, ±9 km." Mr. Smith has, however, neglected the fact that the period of the perturbed orbit has in general been changed, so that although the orbits intersect at least at one point, when one particle returns to this point the other either has not reached it or has already passed it. Moreover, the separation increases steadily at each revolution. This effect of small perturbations is of course familiar to astronomers as the agency which spreads meteoric matter around the orbit of a comet. Only in the particular case where the perturbation results in a change of direction with no change of velocity does the one particle oscillate about the other without moving away from it.

These movements are best demonstrated on a frame of reference whose origin is the unperturbed particle, and whose axes rotate with the particle. Fig. 1 shows the example quoted by Mr. Smith in this way.

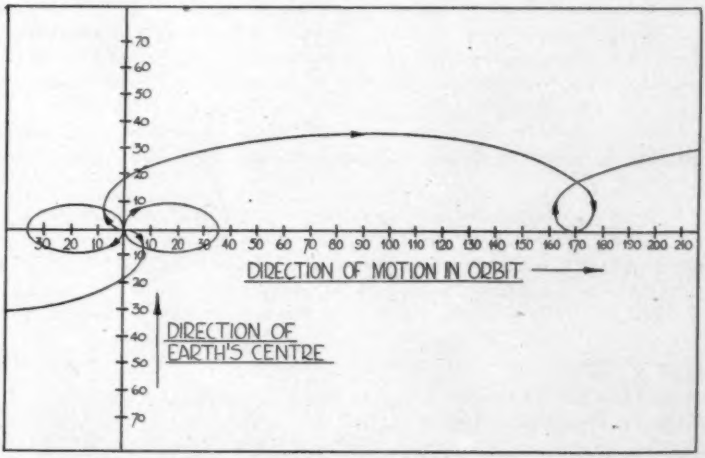


FIG. 1. Relative motion of particles projected at 10 m. per sec. from a circular orbit about the Earth of period 1·58 hr.

Scale in kilometres. Only first cycle of radially perturbed orbits is shown.

It will be seen that the particle given extra tangential velocity moves *backwards* in a kind of cycloid at a mean rate of about 170 km. per revolution,

whilst the retarded particle moves *forwards* by a corresponding amount. The particles given radial impulses move to a first approximation in an ellipse, $a = 18$ km., $b = 9$ km. The orbital period has however been changed by a second order term, which means that both particles have a superimposed uniform backwards drift of about 110 metres per revolution. These ellipses become closed only in the particular case mentioned above, when they represent the relative motion of any particle moving in an ellipse of the same period as the circular orbit chosen.

The case of a change of direction with no change of velocity in the plane at right angles to the radius vector is the only one in which the perturbed particle moves away and returns on the same path, meeting the unperturbed particle half a revolution later.

Perhaps the most interesting application of this analysis is the prediction of "Homing" techniques. Thus, to close the gap between two particles moving in the same orbit the homing particle must be given an impulse *away* from the other particle. A full analysis of these problems is not however the purpose of this letter.

Northwich, Cheshire. C. A. Cross.

Mr. Smith writes as follows:

I think it is possible to lose sight of practical considerations where too much attention is given to the minutiae of academic precision. The conclusions reached by Mr. Cross in relation to "homing" are an instance. Within those ranges where "homing" can be used at all (that is where the separation is small in proportion to the orbital radius) it will always be possible to effect contact by applying an impulse substantially in the direction of the target body, and allowing the automatic homing mechanism to make whatever corrections that may become necessary. To devise a homing system which attempts to guide a missile towards its objective by means of an impulse away from its target would seem a pretty hopeless task.

The point I was trying to make in my paper was that it should be possible to ensure that the seeking body can be brought within homing range of its target without recourse to impractical standards of operational accuracy. All that I sought to do was to establish the order of magnitude of the various factors, and in the present state of the art I think that is all that can profitably be done.

WANTED, the 12 pre-war issues of the *B.I.S. Journal* (Vols. 1–5). M. R. Lloyd, 2, Eastlands Way, Oxted, Surrey.

WANTED, *B.I.S. Journals*, Vol. 6, Nos. 2 and 3, and *Bulletin*, Vol. 2, Nos. 1 and 2. Wodhams, 13, Wallasey Crescent, Ickenham, Uxbridge, Middx.

FORTHCOMING MEETINGS

It has been decided to discontinue recording the many outside lectures undertaken by B.I.S. lecturers in the future, since these have now grown to be so many.

The B.I.S. lectures will continue to be recorded as a reminder to members.

April 5, 1952 (Saturday). "The Problem of Communication with Extra-Terrestrial Beings," by Professor Hogben, to the Society, at Caxton Hall, at 6 p.m.

April 19, 1952 (Saturday). "Film Show and Exhibition," at the North-Western Branch, 49, Lower Mosley Street, Manchester, 2, at 2.15 p.m.

May 10, 1952 (Saturday), "The Design of a Life Compartment Necessary for Interplanetary Travel," by N. R. Nicoll, to the Midlands Branch, at College of Technology, Suffolk Street, Birmingham, 1, at 6.30 p.m.

LARGE APERTURE ASTRONOMICAL TELESCOPES

We are pleased to announce that the new "Astrominor" 5·7" aperture astronomical Newtonian Reflecting Telescopes are now available.

These are equatorially mounted telescopes, with Aluminised mirrors, and range from the simple mounted telescope at £41.0.0. to the fully equipped "Major" model, complete with driving clock, setting circles, slow-motion controls, finder, and numerous other important refinements, at £82.5.0.

Please send a stamped addressed envelope for lists covering these and other interesting products, to:—

THE NORTH WEST OPTICAL CO. (SALFORD) LTD.,
PHOENIX WORKS, BAILEY ST., PENDLETON,
SALFORD 6 (LANCS.)

H. K. LEWIS & Co. Ltd.

Scientific and Technical Booksellers

A SELECTION OF BOOKS ON ASTRONAUTICS, ASTRONOMY AND METEOROLOGY ALWAYS AVAILABLE

LENDING LIBRARY — SCIENTIFIC AND TECHNICAL
Annual Subscription from **TWENTY-FIVE SHILLINGS**

THE LIBRARY CATALOGUE revised to December, 1949, containing a classified Index of Authors and Subjects recently published
To subscribers 17s. 6d. net. To non-subscribers 35s. net, postage 1s. Bi-monthly List of New Books and New Editions added to the Library, sent post free to all subscribers regularly

H. K. LEWIS & Co. Ltd., 136 Gower Street, London, W.C.1
Telephone: EUSton 4282

Sky and TELESCOPE

ASTRONOMY FOR EVERYONE

A popular illustrated monthly on astronomy and related sciences.

Star charts for all the sky; observer's page; telescope-making department; news notes; amateur astronomer's page; latest advances in astronomy.

Subscription: $5.00 *worldwide;* $9.00 *for two years;* $4.00 *U.S. and Latin America;* $7.00 *for two years. Sample copy sent on request.*

SKY PUBLISHING CORPORATION, Harvard Observatory, Cambridge 38, Mass., U.S.A.

Tough enough?..

....you know before it flies!

Fitters, riggers, electricians—the designer gives them his 'O.K.' All worries are past ... All? But what of 'g'? Will the many complex components, the sensitive relays, the fragile valves and electronic gear, and indeed the structure itself stand up to the severe values of 'g' met with in today's supersonic speeds and barrier investigations? Goodmans Vibration Generators provide the added assurance of pre-flight testing. These Vibrators provide *controllable* vibratory sinusoidal forces of frequency and amplitude by which specific anticipated vibratory conditions can be accurately simulated. In this way the behaviour of materials and structures under dynamic loading can be predicted and their resonant responses pre-determined ... You can make sure *before* the machine flies!

Among the many applications of Goodmans Vibration Generators are **HAIRSPRING TORQUE TESTING ● CALIBRATION OF ACCELEROMETERS ● FATIGUE TESTING ● REPEATED FLEXURE TESTING ● DYNAMIC RESPONSE DETERMINATION and a wide variety of industrial uses where specific forms of agitation are required, such as sifting chemicals, powder separation, etc., etc.**

Fullest technical data from "Vibrator" Advertising Dept.

GOODMANS VIBRATION GENERATORS

BRIEF SPECIFICATION OF MODEL 390A

Stroke	½ in. total excursion (up to ¾ in. sinusoidal wave form).
Power Capacity ...	Force factor 4.85 lb. per amp., 2 amps. uncooled. 4 amps. cooled (continuous rating).
Acceleration per amp.	Armature free = 17.0 g; with 2 lb. loading = 2.1 g.
Range	0-10,000 c/s.

GOODMANS INDUSTRIES LTD.
AXIOM WORKS · WEMBLEY · MIDDX.
Telephones: Wembley 1200 (8 lines).

DESIGNERS AND PRODUCERS OF ELECTRO-DYNAMIC TRANSDUCERS FOR OVER 25 YEARS

PRINTED BY W. HEFFER & SONS LTD., CAMBRIDGE, ENGLAND